International Journal of Latest Technology in Engineering, Management & Applied Science (IJLTEMAS)
Volume VIII, Issue IX, September 2019 | ISSN 2278-2540

Design of a Myoelectric Hand Prosthesis System

Shahid Aziz[1], Ozair Ahmad[2], Md Nadeem Enam[3]

[1,2,3]*Assistant Professor, Department of Electronics & Communication Engineering, Maulana Azad College of Engineering and Technology, Patna, India*

***Abstract*— The loss of a hand from amputation or congenital defects causes disability. An " ideal " artificial hand should match the requirements of prosthetics and humanoid robotics. It can be wearable by the user, which means that it can be perceived as part of the natural body and should replicate sensory- motor capabilities of the natural hand. However, such an ideal extraordinary prosthesis is still far from reality eventually leading to low user acceptance of the myoelectric forearm prostheses. Awkward control, lack of feedback and difficult training are considered as primary reasons for the low user acceptance. In this paper, efforts are taken for the design of an artificial myoelectric prosthetic system using computational optimization technique, which will prove to be stable, errorless and hassle free.**

***Key Words*: Myoelectric prosthetic system, amputation, feedback, user acceptance, Computational Optimization technique.**

I. INTRODUCTION

Myoelectric controlled Prosthetic hand is a sensitive artificial device extension that replaces a missing body part. The loss of a hand from amputation or congenital defects causes disability. Prostheses have been developed throughout history to restore some of the hand's original functionality and appearance.. . Prosthetics are important to improve amputees' lifestyles. "Myoelectric" is the term for electric properties of muscles. A myoelectric-controlled prosthesis is an externally powered artificial limb that is controlled with the electrical signals generated naturally by the amputees own muscles A myoelectric prosthesis uses the existing muscles in the residual limb to control its functions. One or more sensors fabricated into the prosthetic socket receive electrical signals when one intentionally engages specific muscles in his residual limb. Sensors relay information to a controller, which translates the data into commands for the electric motors and moves the amputee's joints. The structure of the prosthesis should result in intuitive control to improve user acceptance. The signal flow can be divided into three parts: user intent, motion control, and sensory feedback [1] . A prosthesis should contain subsystems that account for each of these parts. The subsystems are described as follows: electromyographic (EMG) sensing: The sensing part of ME prostheses is based on EMG signals. These signals are the electrical expression of the neuromuscular activation generated by skeletal muscles and contain rich information regarding the motion intended by the user by detecting the activity of residual muscles through electrodes on the skin; control system: Control systems for ME prostheses combine the output signals of the EMG sensing system with data from internal and external sensors to generate the motions intended by the user; and feedback system: Force is the most important type of information for feedback, because it is impossible to determine through visual inspection.. Feedback on the position of the fingers was considered important to reduce the attention required and allow for more intuitive grasping. A combination of both force and position information could provide the user with a measure of object stiffness. With the advent of 21st century, the design and construction of a myoelectric hand prosthesis has shown improvement by leaps and bounds. Some well known commercially available prosthesis design includes Otto Bock Sensor Hand [3], the Utah Arm [4], and the I-Limb Hand from touch bionics [5].

II. DESIGN AND RESULTS

A. System Plant and Control Architcture

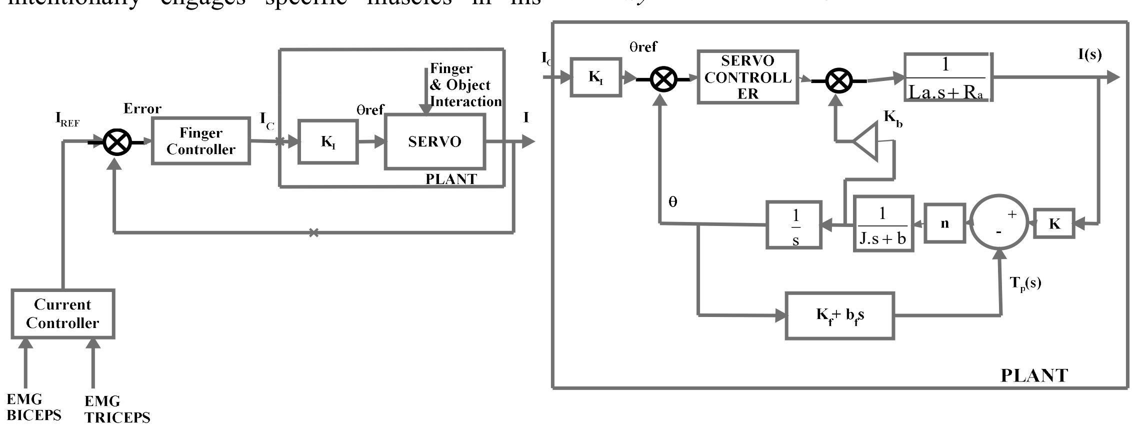

Fig. 1 System Plant and Control Architecture [1]

The first step towards designing the feedback control system is finding the plant model and its parameters. The plant model comprises the actuator coupled to the finger model. The block diagram of the proposed system is shown in the figure(). The plant model is simplified using block diagram reduction techniques up to a simple transfer function that relates output current I(s) and control signal $I_C(s)$, namely the output of the finger controller.

$$\frac{I(s)}{Ic(s)} = \frac{360s+1278}{s^2+44.55s+115} \quad (1)$$

The open loop step response of the above equation, without the proposed current feedback, and the calculation of various parameters such as overshoot value, rise time, settling time and the location of poles is done using a MATLAB code. Open loop step response of the above function shows a high overshoot value = 394.6081 (approximately 400%), rise time = 0.0027 s , settling time = 0.2137 s, location of poles at s = 22.2750 ± i25.6286.

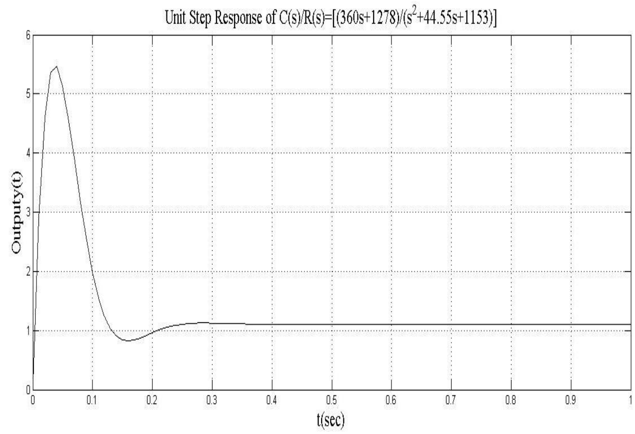

Fig. 2 Unit step response of the plant model

In order to decrease the overshoot value close to zero a phase lead compensator is introduced and the settling time is increased up to approximately 0.6s. The desired locations of the closed loop dominant poles are chosen at s = -4.85± i1.2155 and using Root Locus technique K =32 is achieved.

Thus the transfer function of the phase lead compensator is :

$$C(s) = \frac{32(s+5.96)}{s+40} \quad (2)$$

The overall transfer function is :

$$\frac{I(s)}{Iref(s)} = \frac{68659.20s^2 + 243740.16s}{s^3 + 68743.75s^2 + 246675.16s + 46120} \quad (3)$$

In order to check whether the derived system is stable or not, a MATLAB code is written to plot the step response.

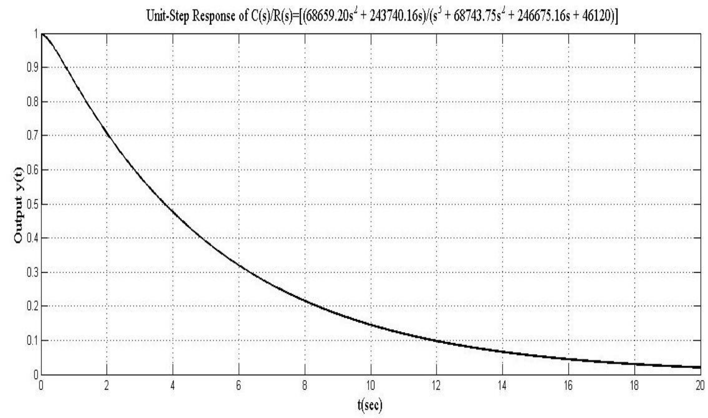

Fig.3 Unit step response of the system using phase lead compensator

B. Design of Controller

From the step response curve of eq() shown in fig() , it can be concluded that it has no rise time, since it reaches to a unit value at time t = 0. Secondly, it can also be seen that the output is decreasing with increase in time i.e it is in under damped condition. Thirdly, it can be said from the above step response that the steady state error of the system is too high. Thus the system is not a stable one. To achieve stability , a controller needs to be introduced. The effects of each of the three controllers(Proportional, Derivative and Integral) on a closed loop system are well known [7]. It is not obligatory to implement all the three controllers into a single system, if not necessary.

The PID controller is given by [8]:

$$G(s) = \frac{K(s+a)^2}{s} \quad (4)$$

$$G(s) = Ks + 2aK + \frac{a^2K}{s} \quad (5)$$

$$G(s) = 2aK\left(1+\frac{s}{2a} + \frac{a}{2s}\right) \quad (6)$$

C. Computational Optimization Approach

Computational optimization approach is used to obtain optimal set of parameter values to satisfy the transient response specifications. In equation (6) the first, second and third term represents the derivative, proportional and integral controller respectively. So, the controller function defined in computational approach is basically a PID controller, whose transfer function is given by:

$$G_C(s) = K_P\left(1+\frac{1}{Kis} + Kd\,s\right) \quad (7)$$

Where K_P denotes proportional constant, K_i denotes integral constant and K_d denotes the differential constant. Comparing equation (6) with equation (7) , the controller parameters are :

$K_P = 2aK$, $K_d = \frac{1}{2a}$ and $K_i = \frac{2}{a}$

So, the controller parameter depends on both 'K' and 'a'. It is desired to find a combination of 'K' and 'a' such that the closed loop system is steady state error free. For designing the system using PI controller, there is no differential controller, i.e $K_d = 0$. The equation for PI controller according to equation (4) reduces to :

$$G(s) = \frac{K(s+a)}{s} \tag{8}$$

From equation (4) the equation for PI controller can also be written as:

$$G(s) = K_P \left[1 + \left(\frac{1}{KiS}\right)\right] \tag{9}$$

Comparing eq (8) and (9), it can be deduced that:

$K = K_P$ and $a = \frac{1}{Ki}$

The proportional constant of the controller K_P = K and integral constant, $K_i = \frac{1}{a}$

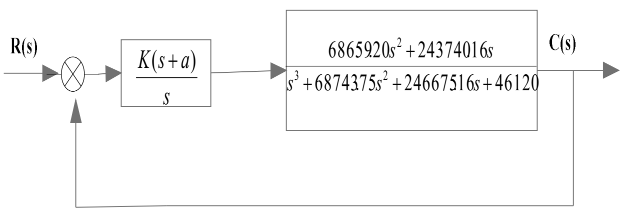

Fig.4 Tuning PI Controller using Computational approach

The transfer function for the overall system is derived and is given by:

$$G(s) = \frac{(68659.2K)s^2 + (68659.2Ka + 243740.2K)s + (243740.2Ka)}{s^3 + (68659.2K + 68743.8)s^2 + (243740.2K + 246675.2 + 68659.2Ka)s + (46120 + 243740.16Ka)} \tag{10}$$

It is desired to find a combination of 'K' and 'a' of the PI controller $\frac{K(s+a)}{s}$ such that the unit step response will exhibit the maximum overshoot between 10% and 2% (1.02≤maximum output≤1.10) and the settling time will be less than 3 sec [6]. Accordingly a MATLAB program is written , wherein it is assumed that 'K' and 'a' are bounded by 1≤K≤20 and 0.1≤a≤6. To avoid large amount of computation, to keep the step size reasonable it is taken as 1 for 'K' and 0.05 for 'a'. Different values of 'K' and 'a' are taken and for each set of value overshoot, 'm' and the settling time 't_s' is calculated. The MATLAB program generates a table of K, a, m and t_s.

TABLE I

DIFFERENT VALUES OF K,a,m and t_s

K	a	m	t_s
20.0000	6.0000	0.9985	0.1500
20.0000	5.9500	0.9984	0.1500
20.0000	5.9000	0.9984	0.1545
19.0000	6.0000	0.9984	0.1600
19.0000	5.9500	0.9983	0.1600
19.0000	6.0000	0.9981	0.1700
18.0000	5.9500	0.9980	0.1800
18.0000	6.0000	0.9979	0.1900
17.0000	5.9500	0.9978	0.2200
17.0000	6.0000	0.9977	0.2400
16.0000	5.9500	0.9975	0.2700
16.0000	6.0000	0.9974	0.3100
15.0000	5.9500	0.9972	0.3400
15.0000	6.0000	0.9970	0.3700
14.0000	5.9500	0.9968	0.4400
14.0000	6.0000	0.9966	0.4700
13.0000	5.9500	0.9964	0.5400
12.0000	6.0000	0.9960	0.6100
11.0000	5.9500	0.9956	0.6600
10.0000	6.0000	0.9950	0.7100
9.0000	5.9500	0.9945	0.7700
8.0000	6.0000	0.9941	0.8300
7.0000	5.9500	0.9935	0.8700
6.0000	6.0000	0.9929	0.9000
5.0000	5.9500	0.9921	0.9300
4.0000	6.0000	0.9910	0.9400
3.0000	5.9500	0.9896	0.9600
2.0000	6.0000	0.9874	0.9750

From the above generated table it is clear that after the pi tuning is done using computational approach, in the case K=20 and a=6, the system become much more stable and acceptable. Thus, considering the above case, we have to use a PI controller with K=20 and a=6 in front of the system to make the overall system stable.

The transfer function of the PI controller is hence given as:

$$G_{PI}(s) = \frac{20(s+6)}{s} \tag{11}$$

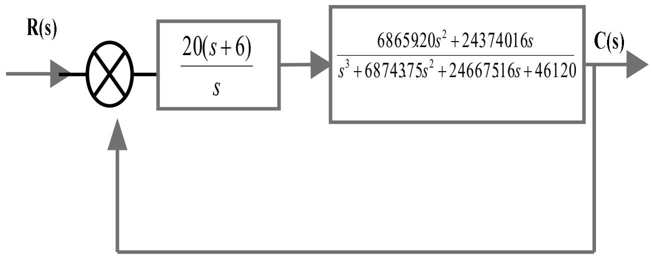

Fig.5 Block Diagram of a Myoelectric hand Prosthetic system with tuned PI controller

The overall closed loop transfer function of the figure() can be calculated and is given by:

$$G(s)=\frac{1373184s^2+8994355.2s+1462440\ .6}{s^3+1441927.8s^2+9241030.4s+14670529} \quad (12)$$

A MATLAB code is written for the above overall transfer function to plot the unit step response.

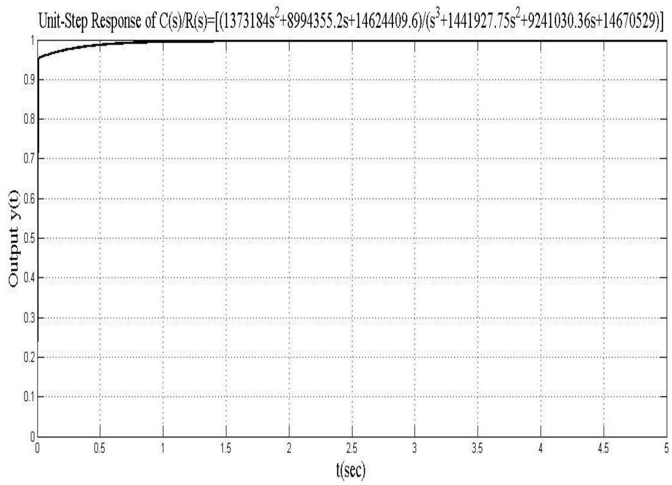

Fig.6 Unit Step Response of the system after using the tuned PI controller

III. CONCLUSION

Stability is the fundamental criterion of efficiency, because unstable systems cannot be realized into practice, which ultimately leads to inefficiency. The above step response obtained for the tuned system having K = 20 and a = 6 shows that the system is almost stable with negligible overshoot value and minimum settling time. Also the steady state error is almost eliminated. The main objective of the paper is to obtain an optimized system out of an unstable system, which is accomplished.

ACKNOWLEDGEMENT

Authors would first of all like to thank the Almighty for HIS constant guidance and benevolence which showed the righteous path amidst darkness . Authors would also like to thank the Director, Prof(Dr) Asim Kumar, Board of Governors, Maulana Azad College of Engineering and Technology, Patna. for their constant motivation.

REFERENCES

[1]. Tálita Saemi Payossim Sono, Luciano Luporini Menegaldo,"Myoelectric Hand Prosthesis Force Control Through Servo Motor Current Feedback" Artif Organs, Vol. 33, No. 10, 2009.p.p-871-876
[2]. Journal of Rehabilitation Research & Development Volume 48, pages 719-738. Myoelectric forearm prostheses: State of the art from a user-centered perspective.
[3]. http://www.ottobock.com/cps/rde/xbcr/ob_us_en/im_646d321_gb_myohand_variplus_speed.pdf
[4]. http://www.ieeecss.org/PAB/csm/columns/Feb2005/Feb2005UtahArm.pdf
[5]. http://www.engadget.com/2007/07/17/touch-bionics-i-limb-bionic-hand/
[6]. Dr. Biswarup Neogi, Debprasad Sinha et al, "Optimal Design of Standard Myoelectric Hand Prostheses System."
[7]. http://www.engin.umich.edu/group/ctm/PID/PID.htm l
[8]. Modern Control Engineering (Fourth Edition) by Katsuhiko Ogata.p.p-692-693

BIOGRAPHIES

Mr. Shahid Aziz received his B.E degree in Electronics Engineering from University of Pune in 2009 and his M. Tech degree in Communication Engineering from West Bengal University of Technology, Kolkata, in 2014.

Since 2011, he is working as an Assistant Professor in the department of Electronics and Communication Engineering, Maulana Azad College of Engineering and Technology, Patna.

Mr. Aziz is a Life Member of Indian Society for Technical Education (ISTE).

Mr Ozair Ahmad received his B.E degree in Electronics and Communication Engineering from Gulberga University in 1998 and his M.E degree in Electronics and Communication Engineering from National Institute of Technical Teacher's Training & Research, Chandigarh, in 2015. He is pursuing his Ph.D. in Wireless Communication from Graphic Era Doon University, Dehradun.

Since 2001, he is working as an Assistant Professor in the department of Electronics and Communication Engineering, Maulana Azad College of Engineering and Technology, Patna.

Mr. Md. Nadeem Enam received his B.Tech degree in Electronics and Communication Engineering from W.B.U.T, Kolkata in 2009 and his M. Tech degree in Communication Engineering from M.A.K.A.U.T, Kolkata, in 2015.

Since 2010, he is working as an Assistant Professor in the department of Electronics and Communication Engineering, Maulana Azad College of Engineering and Technology, Patna.