

48



Proceedings

2012 IEEE Control and System Graduate Research Colloquium (ICSGRC 2012)

16 – 17 July 2012

Faculty of Electrical Engineering
UNIVERSITI TEKNOLOGI MARA
Shah Alam, Malaysia

Organizer

IEEE Control System Society Chapter Malaysia

Secretariat at:

*Centre for System Engineering Studies
Faculty of Electrical Engineering
Universiti Teknologi MARA*

Secretariat

*Mohd Nasir Taib
Rozita Jailani
Mohd Hezri Fazalul Rahiman
Ramli Adnan
Nooritawati Md Tahir
Abd Manan Samad
Megat Syahirul Amin Megat Ali
Ahmad Ihsan Mohd Yassin
Hamidah Mohd Nasir*

Contact Information:

*ICSGRC 2012 Secretariat
Faculty of Electrical Engineering
Universiti Teknologi MARA
40450 Shah Alam
Malaysia*

*Email: rozita@ieee.org
ramli324@salam.uitm.edu.my*

*Tel: 603-55435012
Fax: 603-55435077*



IEEE Catalog Number: CFP1205K-CDR
ISBN: 978-1-4673-2034-4

Copyright and Reprint Permission: Abstracting is permitted with credit to the source. Libraries are permitted to photocopy beyond the limit of U.S. copyright law for private use of patrons those articles in this volume that carry a code at the bottom of the first page, provided the per-copy fee indicated in the code is paid through Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923. For other copying, reprint or republication permission, write to IEEE Copyrights Manager, IEEE Operations Center, 445 Hoes Lane, Piscataway, NJ 08854.
All rights reserved. Copyright ©2012 by IEEE.

Table of Contents

	Page
<i>Copyright</i>	ii
<i>Organizing Committee</i>	iii
<i>Technical Reviewers</i>	iv
<i>Table of Contents</i>	v
<i>Paper Title & Authors</i>	
ID9 Research for Security Strategy of Cloud Service Based On System Survivability Huanan Liu and Shiqing Wang	1
ID10 The Analysis and Design of Trusted Computing Applied into Cloud Huanan Liu and Shiqing Wang	5
ID14 Stability Study of PD and PI Controllers in Multiple Difference Disturbances M. A. Nur Huda, H. A. Kasdirin and A. G. Mohd Ruddin	10
ID18 Feed-Forward Control of Non-Minimum Phase XY Table System Using Trajectory Fuzzy-RLS Hybrid ZPETC Ramli Adnan, Michael Jackson Patrick and Norlela Ishak	15
ID19 Real-Time Control of Non-Minimum Phase XY Table System using Trajectory-Adaptive ZPETC Ramli Adnan, Michael Jackson Patrick and Norlela Ishak	21
ID30 Flood Water Level Modelling and Prediction Using Artificial Neural Network : Case Study of Sungai Batu Pahat in Johor Ramli Adnan , Fazlina Ahmat Ruslan , Abd Manan Samad and Zainazlan Md Zain	27
ID31 Implementation of ODFC for Angular Position Control of Cart-Pendulum Dynamic Model Rajeeb Dey, Abhijit Rajkumar and Aditi Bandyopadhyay	31
ID34 Heading Direction Anticipation Using Visual Feedback System Zairulazha Zainal, Rizauddin Ramli and Mohd Marzuki Mustafa	37

Stability Study of PD and PI Controllers in Multiple Difference Disturbances

M.A. Nur Huda^{1,a*}, H.A. Kasdirin^{2,b} and A.G. Mohd Ruddin^{3,c}
Faculty of Electrical Engineering

UTeM

Melaka, Malaysia

^anurhudamohdamin@student.utm.edu.my

^bhyreil@utm.edu.my

^cdpdruddin@utm.edu.my

Abstract—This paper discusses the stability study of PD and PI controllers in multiple difference disturbances. The multiple difference disturbances in this paper are added to the inverted pendulum model that based on robotic leg application such as pendubot. By applying the pendubot model via MATLAB/Simulink block diagram, the performances between the model and disturbances are compared for stability in the simulation results. The simulation results showed that the PD controller could reduce and eliminate disturbances more effective than PI controller in the pendubot model. Overall, the simulation results are based on stability analysis for the degree of stability, steady state performance and transient response.

Keywords—*inverted pendulum; pendubot; PD controller; PI controller; disturbance*

I. INTRODUCTION

Technology development growth fast onward through over the world including Malaysia. Each part of engineering tools is used to build and design the technology such as robot, all types vehicle, building and others. These technology especially robot application, need a control system approach to organize, monitor and stabilize any movement. Within this control system approach, the robot would operate smoothly. In case, the stability in control system is studied for the robotic leg application.

The robotic leg application gives advantage in the pendubot at which also called the arm-driven that do tasks like manipulating, moving, and painting. The tasks are usually found in industrial automation, architecture and artistic. For the industrial automation as an example, the high quality products are a primary goal to achieve. To achieve the goal, the arm-driven robots are developed more than a workers to maintain the products quality. This quality based on the stability [1] in control system that is being explained by James Clerk Maxwell, Edward John Routh, William Kingdon Clifford, Adam Prize, and Alexandr Michailovich Lyapunov in the latter half of the 19th century. The stability of the robotic leg application in this paper is the main problem for the study purposes with the PD type controller in the multiple difference disturbances.

The PD type controller refers to the familiarity terms of the Proportional (P), Integral (I) and Derivative (D) in the PID controller that are well-known as a conventional controller since the last few years ago. These terms are quite importance in define the gains P, I and D in the root-locus techniques. The root-locus techniques are based on the development of the advanced control systems from the state-space model. The state-space model refers to the inverted pendulum as apply in a robotic leg application such as the pendubot.

In a robotic leg application, the PID controller is not depending by self. Looking through from the previous research, the adapting idea of the PID controller [2], the researcher is preferred to use the PD than the PID controller as the PD controller is based on human naturally acts. Considerably from other authors paper: the study of the development of PI controller for disc speed [3], shows that PI controller is also a quite useful for eliminating and reducing disturbance.

Sometimes, the researcher looking for a wide view of research study, as posted in the article of observer control improves motion [4] by Kristin, found that the observer control enable to eliminate ringing and overshoot, and also solve the problem of the PID loops disable to do. By the way, this paper is focusing on the PD and the PI controllers for comparison stability in the multiple difference disturbances. Based on a few review of the introduction, the minority contents of the paper included the model, the controller design in general view, simulation results, conclusion, acknowledgement and references as following.

II. MODEL

The pendubot of the plant model in this paper is referring to the one of the underactuated model with the only 2encoders. Both encoders measure the speed and position for the DC servomotor and pendulum each. The plant model for a single diagram is showed as following:

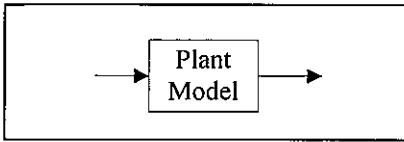


Figure 1. Plant model

Based on the plant model in Fig. 1, the input of the plant model is connected from the output sums of the controller and the disturbance, and the output of the plant model is connected from the output of pendulum. This connection is showed in Fig. 2 as following:

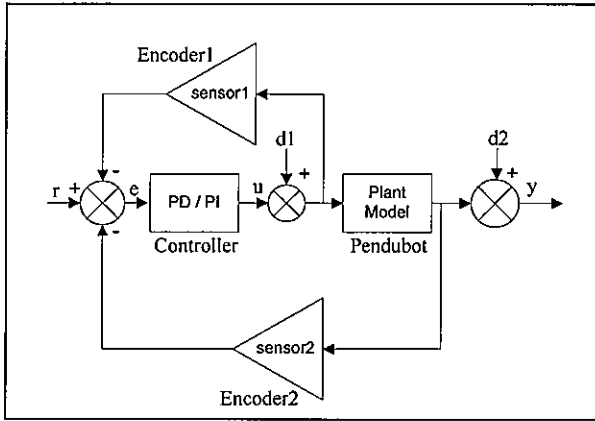


Figure 2. Block diagram for the proposed model of the control system

By the way, the block diagram in Fig. 2 is related to the proposed physical model in Fig. 3 from which is figured as the subsystem in the simulation results. This proposed physical model in Fig. 3 produces the algebra equation of inverted pendulum proposed model by applying the net torque of the DC motor T_m , the torque of disc T_d and the torque of the pendulum T_p at which is expanded into the three separate algebra equations as following:

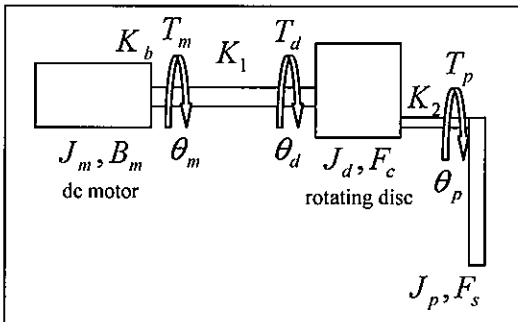


Figure 3. Inverted pendulum proposed physical plant on rotating disc

The torque of the DC motor T_m is derived as:

$$T_m = J_m \ddot{\theta}_m + B_m \dot{\theta}_m + K_1[\theta_m - \theta_d] + d1 + u$$

The torque of the disc T_d is derived as:

$$T_d = J_d \ddot{\theta}_d - K_1[\theta_m - \theta_d] - d1 - u + F_c \frac{\dot{\theta}_d}{|\dot{\theta}_d|}$$

The torque of pendulum T_p is derived as:

$$T_p = J_p \ddot{\theta}_p + K_2[\theta_d - \theta_p] \pm (F_s)|_{\dot{\theta}=0} + d2$$

These derivations are compiled in the state-space equation as following:

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \\ \dot{x}_5 \\ \dot{x}_6 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ -a & a & 0 & -b & 0 & 0 \\ c & -e & 0 & 0 & 0 & 0 \\ 0 & d & f & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ g \\ h \\ i \end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix}$$

Generally, the internal and external disturbances (d_1 or d_2) are placed at the plant input or output, or both points. These disturbances [5, 6] effected to the results output (y) at which considered the closed and the open loop in the control system.

In control system, the disturbances consist like the rejection power sources such as sine, pulse generator and step, environmental source such as wind, machinery source such as vibration, and others. Sometimes, the disturbances that come from the rejection power, environmental and machinery sources are all affected to the one system only.

This paper is focusing to the timer and step disturbances only at which used the PD or the PI controller for the reduction and elimination. By using the timer disturbance, the time period of the system affects with disturbances are identified from the response of the output result. Based on the response of the output result for the timer disturbance, this paper shows that the disturbance is happened for a certain period. Other than the timer disturbance, the step disturbance in this paper presents the final value of the response till infinity, except there is another disturbance coming through the system.

Overall, the sources of disturbances place in the proposed model, with the cascaded [7] loop in control system, give high performance to the results output. The performance of the results output is based on controller (u) design as following section:

III. CONTROLLER DESIGN

This paper proposes the PI and the PD controllers to eliminate or reduce the multiple disturbances. Both controllers are designed by applying the controller transfer function to get the gain values as following:

For the PD type controller,

$$u_1 = K_p + K_d s$$

and for the PI type controller,

$$u_2 = K_p + \frac{K_i}{s}$$

By the way, these controller transfer function is compared the similarity with the compensator of the SISO tool from root locus in MATLAB application. Even though the root locus method quite accurate compared to Ziegler-Nichols Tuning Rule and other methods, but this root locus method is from the figure viewing. This figure viewing gives an advantage to the plant model with multiple disturbances. The plant model is figured as the subsystem for the simulation results as following:

IV. SIMULATION RESULTS

Via the model and the controller design, the rejection power sources or disturbances are added in Fig.4, Fig.5, Fig.6, Fig.7, Fig.8, Fig.9, Fig.10, Fig.11, and Fig.12 to compare the simulation results output. These disturbances are placed at the plant input or output, or both. For the elimination or reduction of disturbances, either the PD or PI controller is placed before the plant in the open loop or closed loop model as following.

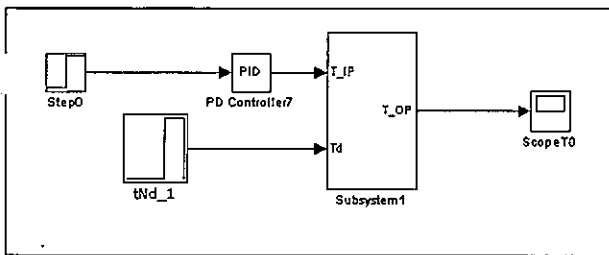


Figure 4. The open loop model with PD controller

By referring to the open loop model with the PD controller in Fig. 4, the disturbance (tNd_1) is placed at the plant input. The plant input is determined the disturbance for the torque of DC motor. Based on control theory, the open loop system does not correct the errors of the model. The errors of the model that are not measured might affect the results output even though the disturbances are eliminated by the PD controller.

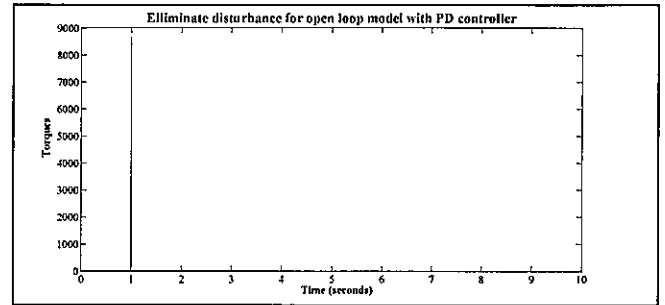


Figure 5. Output disturbance for open loop model with PD controller

The results output in Fig.5 shows that there is no disturbance at all, that gives between 4 to 6 seconds. By the way, there is the highest overshoot of the torque. In control system, the overshoot is not available to use for this model. This is because the highest or maximum torque [8] only available for a wide speed range.

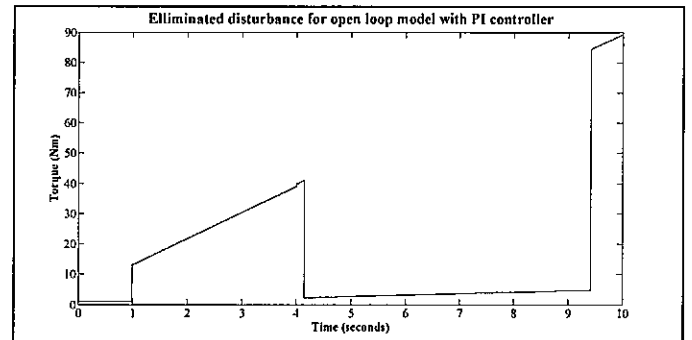


Figure 6. Output disturbance for open loop model with PI controller

In Fig.6 the output response shows a quite difference from Fig.5. The PI controller reduced the maximum overshoot value less than the PD controller for the open loop model with a longer time period after a second to 4 seconds. This response continually shows a gain after 9 to 10 second for at least 90 percent overshoot.

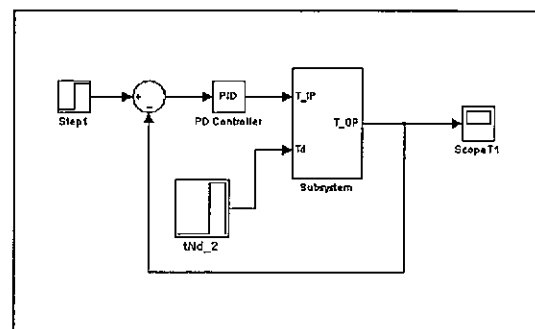


Figure 7. Single disturbance for the closed loop model with PD controller

The single disturbance (tNd_2) of the closed loop model in Fig.7 referred to the timer disturbance. The PD controller for the closed loop model is tuned with a few gains P and D. From the gains tuning, the output response is produced in Fig.8.

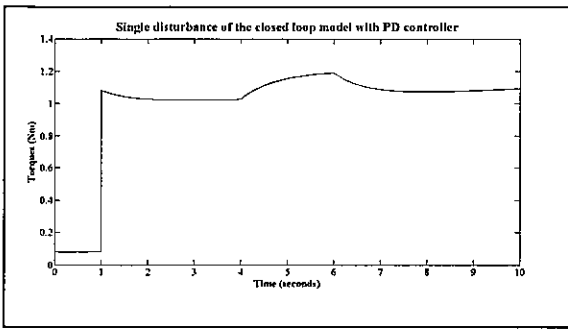


Figure 8. Output of the single disturbance for the closed loop model with PD controller

Based on the single disturbance of the closed loop model in Fig.7, Fig.8 shows that the disturbance presented in between 4 and 6 seconds with the torque range for a zero and one point two. Within the closed loop or also well known as feedback model, the error is corrected. From this output result, the response achieved the steady state more than 6 seconds with more than one Newton meter, torque.

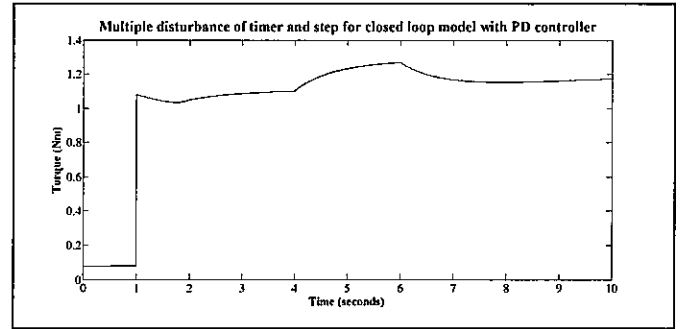


Figure 11. Output for multiple disturbance with PD controller

By using the PD controller to the closed loop model for the multiple disturbances, the output result in Fig.11 shows the response with the disturbances of timer and step. The disturbance of timer began in between 4 and 6 seconds but the disturbance of step began after a second. The multiple disturbances with the PD controller are increased the torque of the response after 6 seconds to achieve the steady state. This steady state shows that a slow response of the time from which is compared to the two previous models.

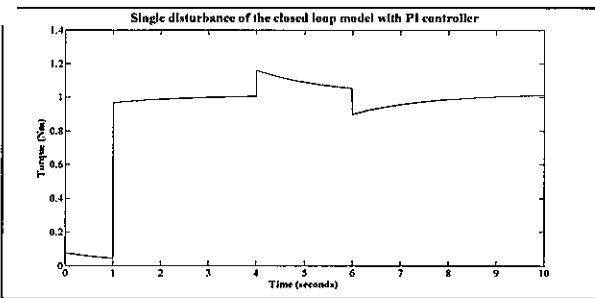


Figure 9. Output of the single disturbance for the closed loop model with PI controller

For comparison output results, the PD controller is replaced by the PI controller in Fig.9. By using the PI controller, the response shows that the increases in the rise time from which is compared to the PD controller based on the tuning of the gains P and I from a high to a low value. From the output result with the PI controller also, the response achieved the steady state earlier than the output result with the PD controller. The output result of a single disturbance with the PI controller only takes a less time from which is compared to the PD controller with the one Newton meter of the torque to stop the simulation.

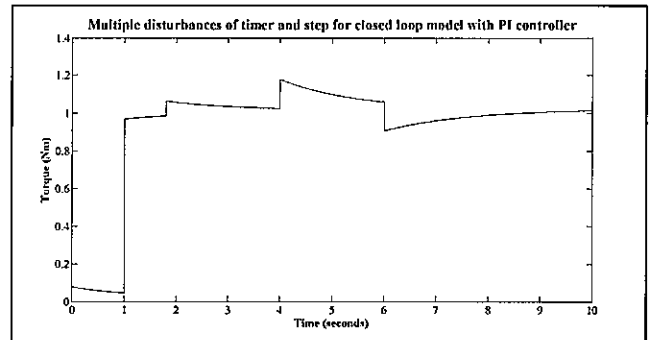


Figure 12. Output for multiple disturbance with PI controller

By the way, the output result for the multiple disturbances with the PI controller in Fig.12 gives a quite similar response of the output result for the single disturbance in Fig.9. For the output result for the multiple disturbances with the PI controller in Fig.12, the response of the two disturbances is figured clearly. The response in Fig.12 with the PI controller is also compared with the response in Fig.11 with the PD controller. In Fig.11, the disturbances are not clearly figured for the response but in Fig.12 the disturbances are clearly figured. These output results for the response in Fig.11 and Fig.12 are caused by the low and the high rise time. Each output results are summarized in Table 1 as following:

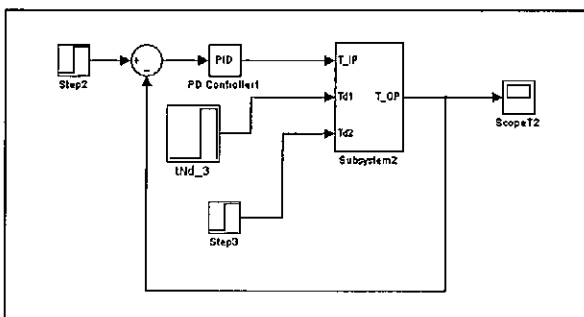


Figure 10. Multiple disturbance of timer and step with PD controller

TABLE 1. Comparison stability for PD and PI controller

Stability Analysis	Controllers	
	Proportional and Derivative (PD)	Proportional and Integral (PI)
degree of system stability	Improves the system stability	As this PI controller increases the compensated by 1, the system show less stable
steady state performance	To satisfy the steady state, the value of K _p must be suited. The constant of the steady state error based on the time, T _d =0 and derivative portion provides no input.	Improves the steady state as its infinite gain at zero frequency
transient response	Improves the transient response with the reduction of the rise time. From the transient response, the maximum overshoot is reduced better than PI controller.	The suitable values of K _p and T _i are selected to improve the transient response. From the transient response, the rise time is increasing and the maximum overshoot is reduced but shows clearer signal.

V. CONCLUSIONS

The multiple disturbances for the proposed model show that a better response of the simulation results output with the cascaded loop. These responses reduce disturbance with the gains tuning of the PD or PI controller for the inverted pendulum proposed model, but low performance for the open loop model from which is compared to the closed loop model. By the way, this simulation results output is not denied at all as the single disturbance gives less problems to the response from which is compared to the multiple disturbances for the stability study. Therefore, the experimental results are followed up for further study.

ACKNOWLEDGEMENT

We would like to express our most gratitude and acknowledgement to the supervisor and researchers from the Faculty of Electrical Engineering, UTeM for their guidance and continuous effort as well as motivation throughout the project and not exempted also to Universiti Teknikal Malaysia Melaka (UTeM), for their financial support.

REFERENCES

- [1] N. S.Nise, *Control System Engineering*: John Wiley & Sons, 2008.
- [2] A. Kadis, *et al.*, "Modelling, simulation and control of an electric unicycle," 2010.
- [3] M. A. Nur Huda, *et al.*, "Development of PI Controller for Disc Speed," in *IEEE Symposium on Industrial Electronics and Applications (ISIEA 2011)*, 2011, pp. 652-656.
- [4] Kristin. (2008, Observer Control Improves Motion

- [5] B. C.Kuo and F. Golnaraghi, *Automatic Control Systems*, 8 ed.: John Wiley & Sons Inc, 2003.
- [6] K. Ogata, *Modern Control Engineering*, Fourth ed. New Jersey: Prentice Hall, 2002.
- [7] Y. Zhong and Y. Luo, "Comparative Study of Single-loop Control and Cascade Control of Third-order Object," *Procedia Engineering*, vol. 15, pp. 783-787, 2011.
- [8] J. Zhi and H. Fengyou, "Maximum torque control of servo motor for wide speed range," in *Electronic and Mechanical Engineering and Information Technology (EMEIT), 2011 International Conference on*, 2011, pp. 3353-3357.

APPENDIXES

Parameters are defined as following:

- J_m = DC motor moment inertia
 J_d = disc moment inertia
 J_p = pendulum moment inertia
 B_m = viscous friction
 F_c = Coulomb friction
 F_s = static friction
 K_1 = torque constant / back e.m.f
 K_2 = spring constant
 $d1$ = disturbance 1
 $d2$ = disturbance 2
 u = PD or PI controller

$$\begin{aligned}
 x_1 &= \theta_m & a &= K_1/J_m & f &= (m_p g l_p - K_2 - m_p l_p a_p)/J_p \\
 x_2 &= \theta_d & b &= B_m/J_m & g &= 1/J_m \\
 x_3 &= \theta_p & c &= K_1/J_d & h &= 1/J_d \\
 x_4 &= \dot{\theta}_m & d &= K_2/J_d & i &= 1/J_p \\
 x_5 &= \dot{\theta}_d & e &= (K_1 + m_d l_d a_d)/J_d \\
 x_6 &= \dot{\theta}_p \\
 \dot{x}_1 &= \dot{\theta}_m = x_4 \\
 \dot{x}_2 &= \dot{\theta}_d = x_5 \\
 \dot{x}_3 &= \dot{\theta}_p = x_6 \\
 \dot{x}_4 &= \ddot{\theta}_m = -\frac{B_m}{J_m} x_4 - \frac{K_1}{J_m} x_1 + \frac{K_1}{J_m} x_2 + \frac{1}{J_m} (T_m \mp (F_{s1})_{\theta_p=0} r_1) \\
 \dot{x}_5 &= \ddot{\theta}_d = \frac{K_1}{J_d} x_1 - \frac{1}{J_d} (K_1 + m_d l_d a_d) x_2 + \frac{1}{J_d} F_c r_1 \\
 \dot{x}_6 &= \ddot{\theta}_p = \frac{K_2}{J_p} x_2 + \frac{1}{J_p} (m_p g l_p - K_2 - m_p l_p a_p) x_3 \pm \frac{1}{J_p} (F_{s2})_{\theta_p=0} r_2
 \end{aligned}$$