Journal of Mechanical, Elecrical & Industrial Technology **Vol. 1 No. 2**
e-ISSN 3047-7778 **September 2024**

Coffee Drying Tool with LQR-PID Control

Sindy Yurisma Sheila[1], Rama Arya Sobhita[1], Anggara Trisna Nugraha[1],
Rachma Prilian Eviningsih[2]

[1]Department of Ship Electrical Engineering, Surabaya State Shipping Polytechnic, Indonesia
(sindy.yurisma@student.ppnas.ac.id)
[1]Department of Ship Electrical Engineering, Surabaya State Shipping Polytechnic, Indonesia
(ramasobhita@student.ppns.ac.id)
[1]Department of Ship Electrical Engineering, Surabaya State Shipping Polytechnic, Indonesia
(anggaranugraha@ppns.ac.id)
[2]Department of Electrical Engineering, Industrial Electrical Engineering Major, Surabaya State Electronics
Polytechnic, Indonesia (rachmaevin@pens.ac.id)

Abstract

Despite Indonesia's status as the third-largest coffee bean producer globally, traditional drying methods may not be sufficient to ensure optimal bean quality, which is heavily influenced by the drying process. This study aims to address this issue by optimizing the drying process through the implementation of a sun tracking system mechanism designed to maximize sunlight exposure. The system continuously adjusts the tray's position to align with the sun's movement, utilizing both mechanical and electrical components. The sensor value serves as the setpoint for the DC motor, which maintains a constant reading. Control methods employed in this study include Linear Quadratic Regulator (LQR) and Proportional-Integral-Derivative (PID) control. Experimental results indicate that the system produces stable responses with optimal PID parameters set at Kp = 10, Ki = 5, and Kd = 2. These findings contribute to determining the most effective controller for enhancing the coffee bean drying process.

Keyword: Controller, LQR, PID

1. Introduction

Coffee is a significant beverage for a large portion of the global population (Saputra, 2018; Aisyah, 2017). Its importance stems not only from the enjoyment it brings to consumers but also from its economic value for countries that produce and export coffee beans, one of which is Indonesia (Astrom, 1995; A.T. Nugraha & R. Arifuddin, 2020). As of 2023, Indonesia ranks as the third-largest coffee producer in the world, following Brazil and Vietnam. This impressive status is largely attributed to the country's rich history of coffee cultivation, which has significantly contributed to the economic growth of Indonesian society (Agung et al., 2021). While the 2022 report by Sugianto & A.T. Nugraha remains relevant, it is essential to consider the most recent statistics to understand current production trends. Indonesia's geographical location further enhances its coffee production capabilities, as it is endowed with microclimates that are particularly conducive to the growth and development of coffee plants.

The process of transforming raw coffee beans, harvested from the trees, into high-quality powdered coffee involves a series of continuous activities that are performed separately using different equipment with distinct operating systems, although these stages have the potential to be integrated. The initial stage involves manually harvesting coffee beans from the trees by farmers. The subsequent stages are carried out sequentially and can be divided into two main groups: primary and secondary coffee processing. Primary coffee processing includes several steps: an initial drying process until the moisture content reaches 25%, removal of the fruit skin, a second drying stage to reduce the moisture content to 12.5%, and sorting. Secondary processing encompasses roasting, cooling, grinding the beans into powder, and packaging. Among these stages, the drying process is critical, as its outcome directly impacts the quality of the coffee beans for subsequent processing, including their transformation into coffee powder. In Indonesia, traditional drying methods are still prevalent, relying on a single direction of sunlight exposure as the sun moves from east to west. To enhance this drying process, this report proposes the use of a DC motor to move the drying tray so that it remains optimally positioned to face the sunlight.

2. Material and methods

2.1. Equipment design stage

During the equipment design stage, a functional block diagram of the planned circuit is created (Anggara &Trihastuti, 2017; Nugraha & Agustina, 2018). Mechanical design is carried out according to the design to facilitate manufacturing (Chusnia & Anggara, 2022; Fahmi & Anggara,2022). Circuit design is performed for each block to facilitate design and determination of the component values to be used (Anggara T. N., 2017; Anggara T.N., 2018; Nugraha & Agustinah, 2018). Software design is done by creating flowcharts for the main

DOI 10.35991/mein.v1i2.6

program and sub-programs. The parts of the device to be designed include: light sensor, drying tray, and DC motor.

2.2. Modeling the System

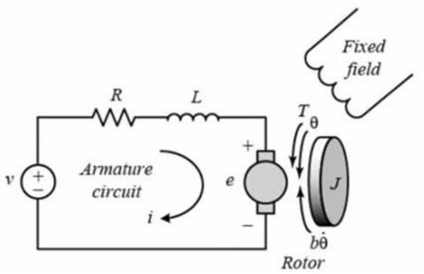


Figure1. Modeling system

This diagram represents a basic model of a DC motor system, illustrating the armature circuit with a voltage source (v), resistance (R), and inductance (L), which drive the armature current (i) and induced electromotive force (e). The rotor interacts with a fixed magnetic field, generating torque (T) and resulting in angular motion (θ) of the rotor. Since this device involves the implementation of DC motor position control, a DC motor circuit is utilized for modeling. This circuit consists of two main parts for analysis: firstly, the electrical system, and secondly, the mechanical of DC motor system. The focus on discussing the electronic system stems from Kirchhoff's law, which states that the total current entering a circuit equals the total current leaving it (Anggara & Trihastuti, 2017; Rahim et al, 2018; Anggara & Jamaaluddin, 2018; Anggara, 2018).

A. Simulation Simulink from Matlab
   1. Script Matlab

```
%Parameter r = 3;
L = 3;
b = 0.1;
K = 0.1;
J = 0.1;

%Statespace
A=[0 1 1 ; 0 -b/J K/J ; 0 -
K/L -r/L];
B = [0;0;1/L]; C = [1 0 0];
D = 0;

%LQR
Q = [1000 0 0 ; 0 10 0 ; 0 0
0];
R = 0.01;
Klqr = lqr(A,B,Q,R);
```

   2. Simulink Model

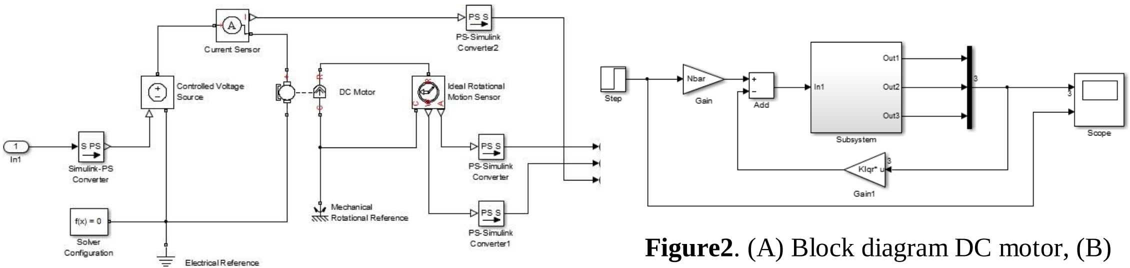


Figure2. (A) Block diagram DC motor, (B) Subsystem DC motor

B. PID Model
   1. Script Matlab

```
%PARAMETER r = 3;
L = 3;
b = 0.1;
K = 0.1;
J = 0.1;
Kb = 0.1;
num = K;
den = [L*J (L*b + r*J) (r*b+Kb*K)]; Gs = tf(num,den)
```

2. Simulink Model

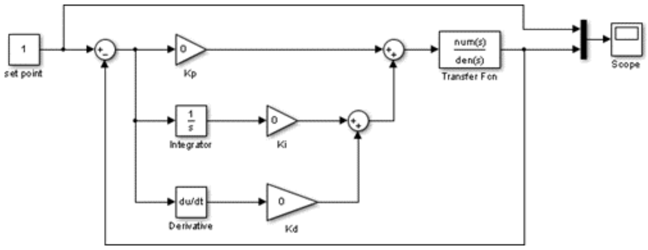
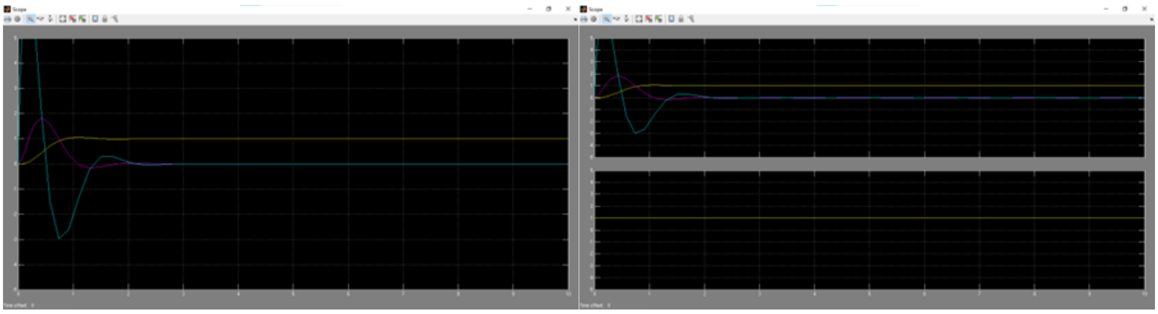


Figure 3. PID Block Diagram

3. Results and discussion

3.1. LQR Control

The input provided to the scope generates a response as shown in the figure below. We can compare the system response graphically against the input. The system has responded quite swiftly and can reach a stable state in less than 2 seconds.



A B

Figure 4. The input provided to the scope generates a response

Next, we will attempt to vary the values of matrices Q and R to form an LQR control. The first variation of matrix Q is [10 0 0; 0 10 0; 0 0 10]. From the generated response graph, it can be observed that the system's response is slowing down.

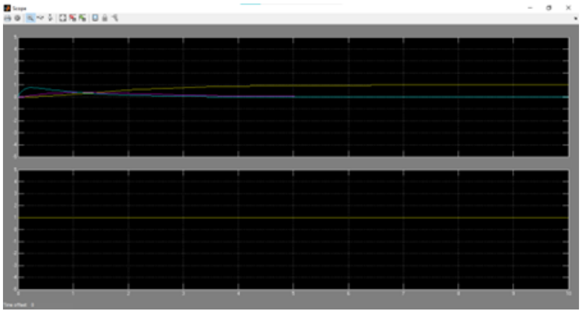


Figure 5. Matrix Q variation 1

For the second variation of matrix Q, we use the values [10 0 0; 0 100 0; 0 0 10]. The response graph generated from this variation of Q values shows that the response deteriorates further, as it does not reach stability even after 10 seconds

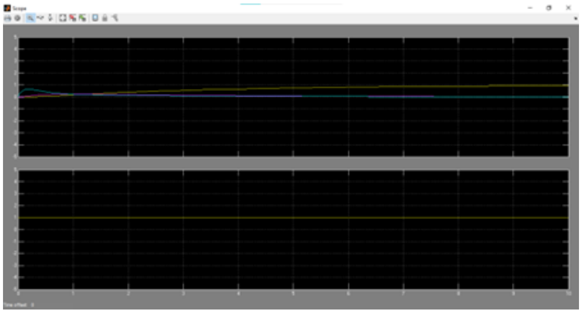


Figure 6. Matrix Q variation 2

Next, we will proceed with varying the value of R, where the value of R is changed to 1. From the generated graph, it can be observed that the system response is not as swift as the system response when using the value of R = 0.01.

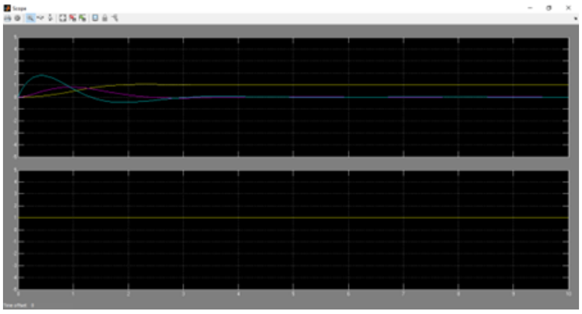


Figure 7. Matrix R variation

The initial input response indicates that the system reaches a stable state in less than 2 seconds. However, variations in the LQR control matrices Q and R demonstrate that increasing the values in matrix Q leads to slower system responses, with the second variation failing to achieve stability even after 10 seconds. Additionally, changing the value of R to 1 results in a slower response. These findings highlight the sensitivity of the system's performance to the selection of Q and R matrix values in LQR control.

3.2. PID Control

In the PID control, the trial and error method is used to determine the parameters Kp, Ki, and Kd. For the first data acquisition, the parameters are set as follows: Kp = 15, Ki = 10, Kd = 2. The resulting graph is shown below. From the graph, it can be seen that the response has reached the setpoint, but it still exhibits oscillations and undershoot. Thus, it can be said that the system is not yet stable.

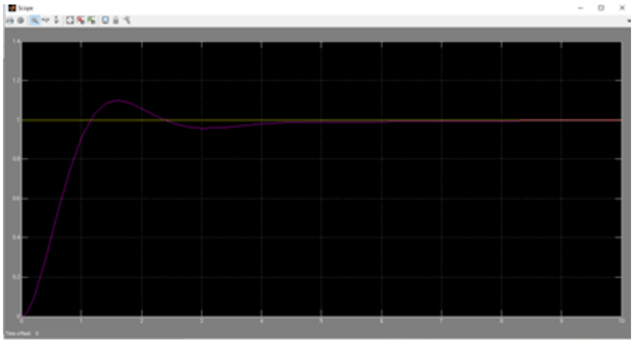


Figure 8. Kp = 15, Ki = 10, Kd = 2

For the second experiment, the parameters are set as follows: Kp = 10, Ki = 5, Kd = 2. From the response results, it can be observed that the response has reached the setpoint without generating oscillations or undershoot, and stability is achieved at the 4th second.

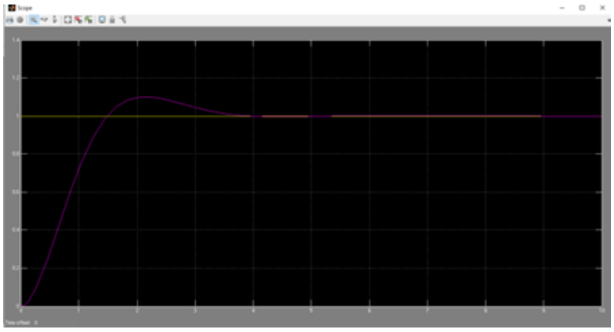


Figure 9. Kp = 10, Ki = 5, Kd = 2

For the third experiment, the parameters are set as follows: Kp = 6, Ki = 4, Kd = 2. From the response results, it can be observed that the response has reached the setpoint without generating oscillations or undershoot, and stability is achieved at the 7th second.

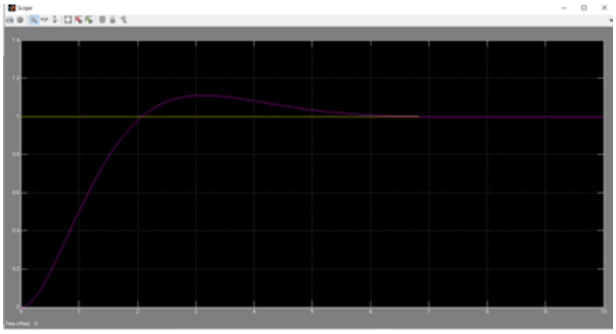


Figure 10. Kp = 6, Ki = 4, Kd = 2

The PID control experiments demonstrated varying effectiveness in achieving system stability. In the first experiment, the system reached the setpoint but exhibited oscillations and undershoot, indicating instability. However, the second experiment with achieved stability at the 4th second without oscillations. The third experiment, using , also reached the setpoint stably, but required slightly longer, achieving stability by the 7th second. These results highlight the importance of parameter tuning in achieving optimal performance in PID control.

4. Conclusion

In the coffee bean dryer device, the sensor value becomes the setpoint value. The DC motor will adjust its position so that the value read by the sensor remains constant. From the experimental results, the following conclusions can be drawn:

1. PID control appears to be more effective and faster to apply. It provided stable responses within a reasonable time frame, while the LQR control's performance was sensitive to matrix variations and required more fine-tuning to achieve stability.
2. From the variation of Q and R matrices in LQR control, it is found that the matrix yielding the best response is R = 0.01.
3. Using PID control, the best response is obtained with the values shown in Figure 6: Kp = 10, Ki = 5, Kd = 2.

Credit authorship contribution statement

Sindy Yurisma Sheila: Conceptualization, Writing – review & editing. **Rama Arya Sobhita**: Supervision, Writing – review & editing. **Anggara Trisna Nugraha**: Conceptualization, Supervision, Writing – review & editing. **Rachma Prilian Eviningsih**: Conceptualization, Supervision, Writing – review & editing.

References

Saputra,wahana.2008.Rancang Bangun Solar Tracking System untuk Mengoptimalkan Penyerapan Energi Matahari pada Solar Cell.Skripsi Universitas Indonesia. Depok

Aisyah, N. (2017). RANCANG BANGUN SISTEM PENGENDALIAN NAMPAN PENGERING BIJI KOPI SATU SUMBU PADA MESIN PENGERING BIJI KOPI BERBASIS PENJEJAK MATAHARI AKTIF DENGAN MIKROKONTROLLER ATMEGA 16. Skirpsi Institut Teknologi Sepuluh November.Surabaya.

Astrom K. Hagglund, PID Controllers : Theory Design And Tuning. Research Triangel Park, Instrument Society, 1995

A. T. Nugraha and R. Arifuddin, "O2 Gas Generating Prototype In Public Transportation," JEEMECS (Journal of Electrical Engineering, Mechatronic and Computer Science), vol. 3, no. 2, Aug. 2020, doi: https://doi.org/10.26905/jeemecs.v3i2.4584.

Agung Prasetyo Utomo, M. Apriani, Ruddianto Ruddianto, Luqman Cahyono, Anggara Trisna Nugraha, and Mochammad Ilham Nugroho, "PELATIHAN PEMBUATAN TERUMBU BUATAN BERBASIS ECO-FRIENDLY SEBAGAI SARANA REHABILITASI TERUMBU KARANG DI DAERAH PANTAI WISATA PASIR PUTIH, SITUBONDO," Integritas, vol. 5, no. 2, pp. 298–298, Nov. 2021, doi: https://doi.org/10.36841/integritas.v5i2.1340.

Moh. G. P. A. Sugianto and A. T. Nugraha, "Implementasi sensor cahaya sebagai level bahan bakar pada tangki harian kapal," Journal of Computer Electronic and Telecommunication, vol. 2, no. 1, Jul. 2022, doi: https://doi.org/10.52435/complete.v2i1.191.

Chusnia Febrianti and Anggara Trisna Nugraha, "Implementasi Sensor Flowmeter pada Auxiliary Engine Kapal Berbasis Outseal PLC," Journal of Computer, Electronic, and Telecommunication, vol. 3, no. 2, Dec. 2022, doi: https://doi.org/10.52435/complete.v3i2.188.

Fahmi Ivannuri and Anggara Trisna Nugraha, "Implementation Of Fuzzy Logic On Turbine Ventilators As Renewable Energy," Journal of Electronics, Electromedical Engineering, and Medical Informatics, vol. 4, no. 3, pp. 178–182, Jul. 2022, doi: https://doi.org/10.35882/jeeemi.v4i3.236.

Anggara Trisna Nugraha, "TRACKING QUADCOPTER MENGGUNAKAN METODE COMMAND-GENERATOR TRACKER DENGAN EFEK INTEGRATOR," Jurnal Teknologi Elektro, vol. 8, no. 2, p. 143151, May 2017, doi: https://doi.org/10.22441/jte.v8i2.1608.

Anggara Trisna Nugraha, "DESAIN KONTROL OUTPUT FEEDBACK DENGAN COMMAND GENERATOR TRACKER BERBASIS LOS PADA JALUR LINGKARAN MENGGUNAKAN QUADCOPTER," Jurnal Teknologi Elektro, vol. 9, no. 2, pp. 73–78, Oct. 2018, doi: https://doi.org/10.22441/jte.v9i2.4070.

A. T. Nugraha and T. Agustinah, "Quadcopter Path Following Control Design Using Output Feedback with Command Generator Tracker LOS Based At Square Path," Journal of Physics: Conference Series, vol. 947, p. 012074, Jan. 2018, doi: https://doi.org/10.1088/1742-6596/947/1/012074.

Anggara Trisna Nugraha and Trihastuti Agustinah, "Quadcopter path following control design using output feedback with command generator tracker based on LOS," Aug. 2017, doi: https://doi.org/10.1109/isitia.2017.8124090.

A. T. Nugraha and T. Agustinah, "Quadcopter Path Following Control Design Using Output Feedback with Command Generator Tracker LOS Based At Square Path," Journal of Physics: Conference Series, vol. 947, p. 012074, Jan. 2018, doi: https://doi.org/10.1088/1742-6596/947/1/012074.

Anggara Trisna Nugraha and Trihastuti Agustinah, "Quadcopter path following control design using output feedback with command generator tracker based on LOS," Aug. 2017, doi: https://doi.org/10.1109/isitia.2017.8124090.

R. Rahim et al., "Congklak, a traditional game solution approach with breadth first search," MATEC Web of Conferences, vol. 197, p. 03007, 2018, doi: https://doi.org/10.1051/matecconf/201819703007.

Anggara Trisna Nugraha and Jamaaluddin, "Setting Neuro-Fuzzy PID Control In Plant Nonlinear Active Suspension," Journal of Physics: Conference Series, vol. 1114, no. 1, pp. 012063–012063, Nov. 2018, doi: https://doi.org/10.1088/1742-6596/1114/1/012063.

Anggara Trisna Nugraha, "DESAIN KONTROL OUTPUT FEEDBACK DENGAN COMMAND GENERATOR TRACKER BERBASIS LOS PADA JALUR LINGKARAN MENGGUNAKAN QUADCOPTER," Jurnal Teknologi Elektro, vol. 9, no. 2, pp. 73–78, Oct. 2018, doi: https://doi.org/10.22441/jte.v9i2.4070.