HOW THE PERFORMANCE OF A DC MOTOR SYSTEM IS IMPACTED BY NOISE

Rizky Fitra Kurniawan[1], Muhammad Hanif Mudhoffar[2], Anggara Trisna Nugraha[3], Laili Agustin Widyaningrum[4]

1Study Program of Automation Engineering, Shipbuilding Institute of Polythecnic Surabaya, Indonesia
2Study Program of Welding Engineering, Shipbuilding Institute of Polythecnic Surabaya, Indonesia
3Study Program of Marine Electrical Engineering, Shipbuilding Institute of Polythecnic Surabaya, Indonesia
4Study Program of Safety And Health Engineering, Shipbuilding Institute of Polythecnic Surabaya, Indonesia

E-mail: rfitra@student.ppns.ac.id

ABSTRACT
The rapid and effortless evolution in different realms of this era includes the sustainable advancement of technology, exerting significant influence on various facets. The expansive nature of technology and information underscores its versatility. Observing these progressions, the ongoing development of science emerges as an inevitable outcome, drawing upon existing knowledge and perpetuating studies to enhance future functionality. The optimization of knowledge through the examination of its evolution proves instrumental in facilitating innovation for future generations, ensuring more efficient and ergonomic utilization. So, considering the substantial electricity demands in the industry, which rely on evenly spread energy sources, it's crucial to find a method for efficiently managing this demand. This involves delving into the realm of science, particularly in the context of propulsion engines. Through research, one can explore how system optimization impacts the effectiveness of control methods like LQR and LQT, especially when additional noise is introduced to the DC motor load system

Keyword: *Maximization of performance, direct current motor, sound reduction, management, and linear quadratic regulator*

1. INTRODUCTION

Human life and technology have become intertwined, as the inherent nature of technology significantly eases various aspects of human existence [1]. The evolving nature of technology inherently involves progress. Consequently, possessing a fundamental grasp of electrical equipment is crucial for one's future. Electrical machines encompass a wide array of functions, making the study of them extensive [2]. To streamline this, scientific optimization focuses on a specific aspect, such as DC Motor electric machines, due to their significant industrial relevance in electricity applications [3]. Through effective optimization, circuits can operate more efficiently and ergonomically than ever before [4].

In this modern era, the growing demands of industries necessitate reliable electricity [5]. To ensure optimal performance of the diverse types and functions of industrial machinery, it is crucial to have a comprehensive understanding and regular updates [7]. Additionally, various forms of periodic maintenance are essential to ensure the efficient operation of electrical machinery [8]. Delving into the intricacies of DC motors, commonly employed in machinery, is a vital subject worth exploring

extensively [9]. A thorough study can enhance their efficiency and utilization [10]. Successful research outcomes can contribute to the progress of electricity usage in the industrial sector through optimization [11].

This research aims to generate insights that could lead to innovative perspectives on the application and functioning of DC motors in the industrial sector [12]. These motors play a crucial role in powering machinery within the industrial realm, and the study aspires to provide fresh ideas for their use and operation [13].

2. METHODOLOGY
2.1 Direct Current Motor

A DC motor is a gadget that transforms electrical energy into motion or kinetic energy. It falls under the category of electric machines, with direct current motor being a specific. The rotational movement is generated through the response of creating a magnetic or electromagnetic field recreation within the motor body [14]. DC motors find extensive use due to several reasons. One key factor is their prevalence in industrial settings where DC power systems are still commonly employed [15]. Moreover, even in the absence of a dedicated DC power system, a rectifier

circuit can be employed to generate the required DC power source, as highlighted by Aldi and Hambali in 2020. The effectiveness of motor rotation is evident in its consistent speed throughout the entire operational cycle, measured by the number of revolutions per minute (RPM) from startup to completion [16]. Achieving a stable motor rotation entail optimizing the system to maintain uniform speed from start to finish. The research employs the following transfer function:

  A. Orde 1

$$K = \frac{T}{I} \quad …(1)$$

$$G(s) = \frac{K}{Ts+K} …(2)$$

[1] Equation for determining the constant value
[2] Equation for determining a first-order mathematical model

K represents the constant, T stands for Torque in Newton-meters, and I denote Current.

2.2 Single Input, Single Output

SISO, or Single Input-Single Output, refers to a control system employing a solitary variable [18]. This system operates with a singular input sender and a corresponding output receiver [19]. It adopts an interconnected network approach, where components collaborate and function collectively to accomplish specified objectives. The input in a control system is what we aim for, while the output is the real state of things or the system's response (Kunto Aji & Diana, 2022). This system, among various types, is the most basic [20]. It employs commands, varying from first-order to more complex orders. The controlled object is a SISO (single-input single-output) system, whether it's first-order, second-order, or higher.

2.3 Multiple input, single output

MISO, short for Multiple Input-Single Output, functions as a wireless communication system akin to SISO and SIMO [21]. However, what sets it apart is its utilization of multiple inputs or senders, with just one output or receiver [22]. Positioned as the third generation of smart antennas following SISO and SIMO, MISO has been found to exhibit superior accuracy compared to SISO in a study conducted by Michael and Stenly in 2021. Essentially, the MISO system can be viewed as the inverse counterpart of SIMO [23].

2.4 Multiple inputs, Multiple output

MIMO (Multiple Input-Multiple Output) functions in wireless communication much like other systems, with a key distinction it employs multiple input sources and multiple output receivers [24]. Utilizing at least two antennas, MIMO technology stands out for its capacity to handle diverse inputs and outputs simultaneously, as demonstrated in Maria's work on designing circular patch MIMO microstrip antennas for 4G LTE technology (2021). MIMO technology represents an advancement from traditional wireless methods, such as Single Input Single Output (SISO) technology, as highlighted by Maria and Andi in their study on the impact of Multi Input Multi Output (MIMO) antenna techniques on 4G LTE network performance at a frequency of 1800 MHz (2019). In the realm of MIMO systems, the pivotal role is played by the control system's interaction process, as emphasized by Wahyudi, Bayu, and Budi. This control system serves as a response to the growing need for enhanced system performance in the present era. Its primary objective is to enable simultaneous data transmission, thereby optimizing delivery in alignment with the channel capacity, as discussed by Dian, Deni, Adi, and Muttaqin in 2022. This MIMO system earns its Smart Antenna label by delivering impressive performance to fulfil current requirements while efficiently handling substantial information without the need for excessive bandwidth. In the realm of modern wireless communication, the emphasis is on achieving the highest possible data rate without disruptions (Sujatha, Subhas, & Giriprasad, 2022). Certainly! MIMO comes with its perks, but there are drawbacks too. These include data reception delays and the time needed for transmission due to signal division among antennas. MIMO operates by sending diverse data sets simultaneously at the same frequency, enhancing system performance [25]. In the context of a MIMO system, the transfer function is aptly represented by the transfer function matrix.

2.5 Single input, Multiple output

SIMO, or Single Input-Multiple Output, is a wireless communication setup that employs a single sender/input and multiple receivers/outputs. It represents a more sophisticated version of SISO, offering advantages such as enhanced receiver speed and the ability to address multipath-related challenges. This configuration is commonly employed in radio transmitters.

2.6 Clamour

Noise, also known as interference, disrupts acoustic, electrical, or electronic signals within a system. This disturbance leads to changes in the signal, hindering the attainment of the desired outcome. In communication, an unadulterated sound signal is crucial for conveying information effectively. When noise infiltrates the original signal, it weakens, ultimately rendering the sound signal ineffective. Typically, any signal captured during data acquisition that disrupts the desired main signal is considered. Noise comes in different types, with white noise being the most frequently encountered— it's essentially a mix of diverse disturbances transmitted through the air.

2.7 Optimal Controller for Linear Systems

Linear Quadratic Regulator (LQR) stands out as a prime choice among optimal control techniques

employed in state space-oriented systems. Its application as a control mechanism is prevalent in various industrial endeavours. When utilized as a controller, LQR necessitates the determination of two parameter values to generate the intended control action.

The LQR control approach operates by adjusting the Q and R matrices to derive an optimal K value, influencing the system's response in line with specified requirements. These parameters are expressed as matrices containing Q and R weights.

2.8 Tracking using Linear Quadratic Control

LQT stands for Linear Quadratic Tracking, a control technique designed to minimize the performance index while regulating the system to follow a specified reference. In simpler terms, LQT aims to make the system output, denoted as y, closely match the output of a reference model while minimizing a specified performance index.

2.9 Investigation Phases

Organizing the research phases is essential for establishing a well-structured study. By outlining straightforward and comprehensible steps, the goal is to ensure that the research contributes to society or sparks inspiration. The subsequent sections outline the various stages of the conducted research:

Compile the datasheet for the DC motor slated for research purposes. Crunch the numbers to derive the first-order and second-order transfer functions of the motor. Construct a simulation circuit in Matlab Simulink mirroring the operational dynamics of the research system. Once the data is gathered and the circuit is set, integrate the first-order and second-order transfer functions into the system. Conduct experiments for single-input single-output (SISO), single-input multiple-output (SIMO), multiple-input single-output (MISO), and multiple-input multiple-output (MIMO) communications.

Capture and analyze the waveform data emanating from the research findings. Repeat the process in stage 5, but this time, introduce additional noise. Iterate through stage 5 and stage 6, incorporating Linear Quadratic Regulator (LQR) and Linear Quadratic Tracking (LQT) control methods in each experiment.

Compare the performance outcomes of the DC motor system under noise-free conditions versus scenarios with added noise. Evaluate and contrast the effectiveness of LQR and LQT control in each experiment.

The narrative above outlines the research phases, aiming to enhance readers' comprehension of the sequential research process. Additionally, we illustrate the experimental procedures through a flowchart diagram. The following is a detailed discussion of these steps depicted in the flowchart.

2.10 Diagram Block

Block diagrams for this round will visually illustrate the anticipated outcomes of the practicum. The elements are categorized into three parts: Input Components, Output Components, and Processes.

LQR Block Diagram Here's a visual representation of the LQR simulation in block diagram form.

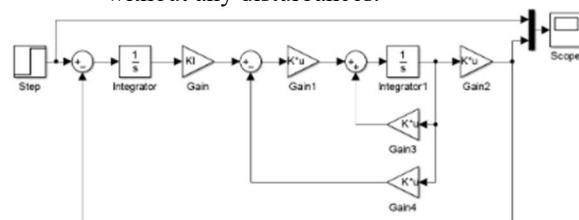a. Reword Linear Quadratic Regulator without any disturbances.

Figure 1. Reword linear quadratic regulator without any disturbances.

The diagram illustrates the LQR circuit in action using the Matlab Simulink program.
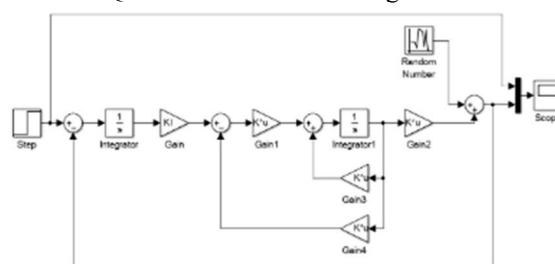
b. LQR with some added background buzz.

Figure 2. LQR with some added background buzz.

The diagram depicts the LQR circuit incorporating additional noise and being run using MATLAB Simulink software.

2.11 Examining the prerequisites of a system.

In the experimental setup, the simulation circuit incorporates various components essential for its operation. The following list enumerates the components integrated into the simulation circuit.

Table 1. The components incorporated into the simulation circuit

No	Element Identifier	Change of locale.	The way it operates
1	Step	Positioned at the circuit's outset as either the input or entrance.	Insert information or data into the simulation.

No	Element Identifier	Change of locale.	The way it operates
2	Sum	Situated following the step or beyond the transfer function block.	When you incorporate multiple inputs and their corresponding feedback into the simulation, it results in the creation of a transfer function.
3	Integrator	Follows Sum or serves as the central component of the simulation.	Simulating the control of a DC motor system to achieve internal gain
4	Gain	Existing post the clamor and prior to the extent, guiding towards the total once again.	Describe how the sensor system operates in the context of simulation work.
5	Noise	Right before the scope concludes, within the transfer function	Adds disturbance to the output signal of the transfer function.
6	Scope	Reach the conclusion of the simulation procedure.	Record the signal or waveform from the simulation outcomes for examination.

The provided table details the components incorporated into the simulation circuit. This comprehensive breakdown facilitates a clearer comprehension of the functionality and placement of each simulation element.

2.12 System Flowchart

The process of research should be presented in a clear and informative manner for readers to comprehend easily. It's crucial to articulate the steps and create a well-structured flowchart diagram. A poorly designed flowchart may indicate a flaw in the system or device being developed, as shown in the diagram below:

The chart depicted here is a type of flowchart showcasing the various phases of this research project. It kicks off by identifying the DC motor

datasheet selected for investigation. Subsequently, the focus shifts to determining the first-order and second-order transfer functions of the DC motor. The next step involves configuring the simulation circuit in MATLAB Simulink, ensuring it aligns accurately with the communication type (SISO, SIMO, MISO, and MIMO). Optimal LQR and LQT methods are then applied. If any discrepancies arise, a return to the previous step is necessary. Sure thing! First, set up the simulation circuit, then proceed to simulate it with the embedded transfer function.
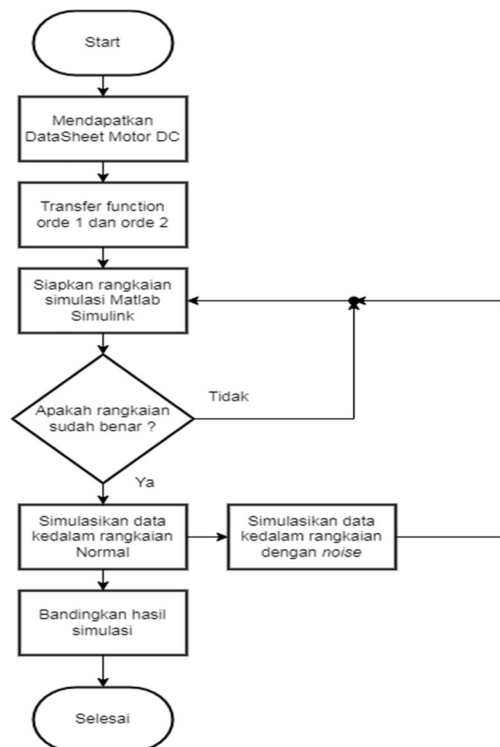

Figure 3. System flowchart showcasing the various phase of this research project.

Following that, simulate the circuit once more, but this time introduce some noise. Afterward, compare the simulation results to identify any noteworthy differences. Once this series of steps is completed, the research stage for this iteration is finished.

3. RESULTS AND DISCUSSIONS

The conducted research yields satisfactory outcomes, with results derived from comparing waveforms in both noisy and noise-free experimental settings. The study involves analyzing waves generated by mathematical models of 1st and 2nd order DC motors through MATLAB Simulink software. Subsequent to this introduction, a detailed discussion follows for each experiment.

3.1 Expressing real-world phenomena using mathematical structures

This study will assess the DC motor using a MATLAB software simulation, eliminating the need for actual hardware. Instead, all that's needed is the conversion of the DC motor's datasheet or specifications into mathematical representations. The provided datasheet contains information about the motor used in the practical application.

Tabel 2. Conversion of the DC motor's datasheet or specifications into mathematical representations

Nominal Voltage	12Vdc
Body Diameter	32
RS Stock no	224-3530
Rotations per Minute at Standard Speed	3700
Torque [mNm]	7,7
Output Power [W]	3
Input Power, No Load [W]	1,2
Input Current, No Load [A]	0,1
Security level	IP40
Max usable power [W]	3,9
Start torque [mNm]	30
Start current [A]	1,5
Resistance [Ω]	8
Inductance [mH]	10
Weight [g]	96
Life [h]	2000
Ratio	125:1

The information extracted from the datasheet of the mentioned DC motor allows us to derive a matrix model that serves as the primary data for the simulation. The research employs a first-order transfer function for analysis.

$$K = \frac{T}{I} = \frac{0,0077}{0,1} = 0,077$$

The DC motor details include the following specifications:

Torque (T) = 7.7 millinewton-meters = 0.0077 Newton-meters

Constant (K) = 0.077

Resistance (R) = 8 ohms

Inductance (L) = 10 millihenries

The outcomes of the conducted calculations yield the matrix model value, employed as a simulation system in Simulink MATLAB.

3.2 LQR in a noise-free environment

This study will showcase the outcomes obtained from running the MATLAB Simulink simulation program on a properly functioning system. These results will serve as a baseline for comparing the performance of the motor when there is no interference or noise.

3.2.1 Single input, single output

The Simulink software illustrates the Single Input-Single Output (SISO) system, featuring a circuit with a sole input/sender and a single output/receiver. This configuration is depicted in the Matlab Simulink software.
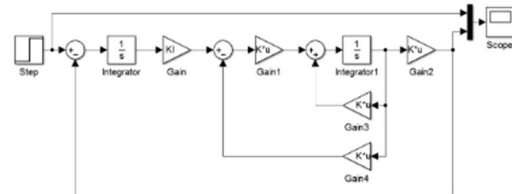

Figure 4. Single input, single output of LQR in a noise-free environment

In the image provided, you can observe the configuration of a circuit featuring a sequence of components. It initiates on the left side with a step component introducing voltage into the circuit. The voltage then progresses to the sum, with one branch capturing feedback from the final waveform outcomes. Another branch extends to the Integrator, followed by integral control for gain. The circuit then splits, with one branch leading to gain B and another branch receiving feedback on the KK gain results. The gain B branch further proceeds to Integrator1, followed by gain C, ultimately concluding at the scope. Simultaneously, the original waveform from the step component travels directly to the scope for comparative analysis.

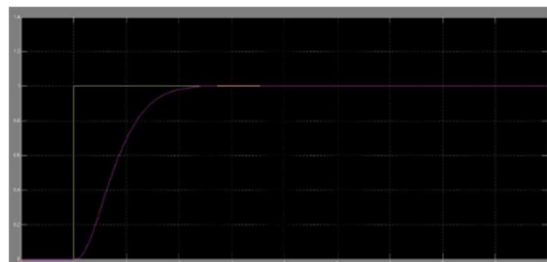The waves generated from the circuit run on MATLAB Simulink software are as follows:

Figure 5. Graph outcomes of the signals received by the scope in the SISO circuit utilizing the LQR control approach

The graph above depicts the outcomes of the signals received by the scope in the SISO circuit utilizing the LQR control approach. The signals manifest in two distinct colours, each indicative of the voltage circulating within the circuit. The yellow signal corresponds to the unaltered voltage sourced directly from the supply. Conversely, the purple signal represents the outcomes after undergoing the LQR method. The yellow signal exhibits a pronounced and abrupt spike, characteristic of the unoptimized original voltage. In contrast, the purple signal displays a more gradual shape, closer to the set point, reflecting the optimization achieved through the LQR method.

3.2.2 Single input, multiple output

The Simulink software showcases a Single Input-Multiple Output (SIMO) system, characterized by a circuit with a singular input/sender and multiple outputs/receivers. The configuration of the SIMO circuit is structured within the MATLAB Simulink software in the following manner:
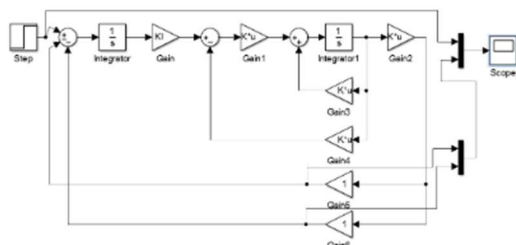
Figure 6. Circuit single input, multiple output of LQR in a noise-free environment.

In the image above, you can observe the configuration of a circuit comprising various components. It initiates on the left with a step component introducing voltage into the circuit. The voltage then progresses to the sum, with one branch capturing feedback from the final waveform results, while another branch proceeds to the Integrator. Following the Integrator, there's control over gain integral, and the circuit further branches out. One branch leads to gain B, and another branch incorporates feedback on the outcomes of gain KK. The branch connected to gain B continues to Integrator1, followed by gain C, and then flows through gain5 and gain6, ultimately reaching the scope. Meanwhile, the original waveform from the step component is directly fed to the scope for comparison.

The waveforms produced by the circuit and simulated using MATLAB Simulink software are as described below:
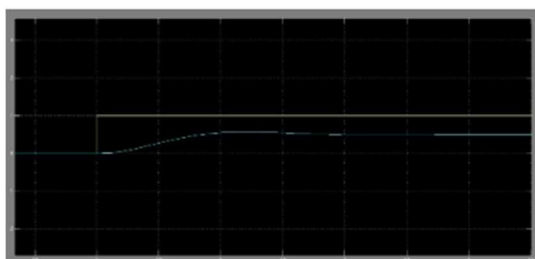
Figure 7. Diagram outcomes of the waves detected by the scope within the SIMO circuit.

The diagram depicts the outcomes of the waves detected by the scope within the SIMO circuit. The wave is split into two segments, distinguished by yellow and cyan colours. The yellow wave signifies the initial signal from the supply prior to implementing the LQR method for optimization. Meanwhile, the cyan wave reflects the signal post

LQR method application. Notably, the cyan wave falls short of reaching the setpoint indicated by the yellow wave, indicating suboptimal performance in this communication system.

3.2.3 Multiple input, single output

The Simulink software illustrates the MISO (Multiple Input-Single Output) system, characterized by numerous inputs/senders and a single output/receiver, through a compiled circuit in MATLAB.
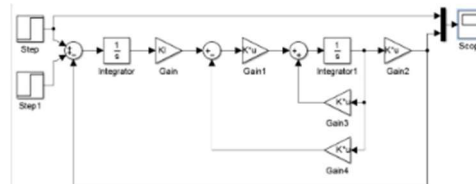
Figure 8. Circuit multiple input, single output of LQR in a noise-free environment

In the image provided, you can observe the configuration of a circuit, featuring a series of components. The circuit initiates on the left with two step components that draw voltage into the system. The voltage then proceeds to the sum, where one branch captures feedback from the final waveform outcomes, and another branch advances to the Integrator. Following this, there is integral control gain, and a subsequent branching occurs. One branch leads to gain B, while the other branch incorporates feedback on the KK gain results. The branch connected to gain B then extends to Integrator 1, followed by gain C, ultimately concluding at the scope. The original waveform from the initial step flows directly to the scope for comparative analysis.

The waveforms produced by the circuit in MATLAB Simulink software are outlined below:
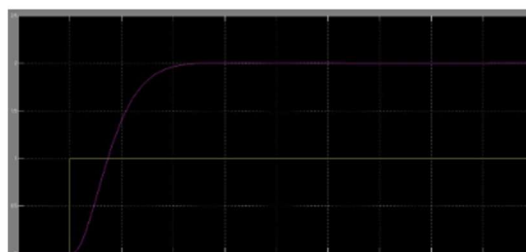
Figure 9. Graph outcomes of the waves detected by the scope in the MISO circuit using the LQR control approach.

The graph above displays the outcomes of the waves detected by the scope in the MISO circuit using the LQR control approach. Two distinct colors represent the voltage within the circuit. The yellow wave depicts the unaltered voltage directly from the source, while the purple wave illustrates the signal outcomes post-application of the LQR method. The yellow wave exhibits a pronounced, elevated spike, characteristic of the unoptimized original voltage. In

contrast, the purple wave surpasses the setpoint of the yellow wave, indicating a voltage doubling at the input despite optimization efforts through the LQR method.

3.2.4 Multiple inputs, Multiple output

The Simulink software showcases a MIMO (Multiple Input-Multiple Output) system with numerous inputs/senders and outputs/receivers, depicted as a circuit compiled within Matlab Simulink.
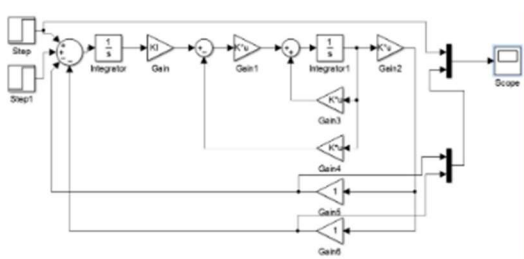

Figure 10. Circuit multiple input, multiple output of LQR in a noise-free environment

The image displays a circuit configuration featuring various components. It commences on the left with two step components drawing voltage into the circuit. The voltage flow progresses towards the sum, where one branch captures feedback from the final waveform results. Another branch extends to the Integrator, followed by integral control and further branching. One branch leads to gain B, while another receives feedback on the KK gain results. The gain B branch continues to Integrator1, then to gain C, and flows through gain5 and gain6, ultimately reaching the scope. The original wave from the step component is directly streamed to the scope for comparison.

The signals produced by the circuit and simulated using MATLAB Simulink software are as described below:
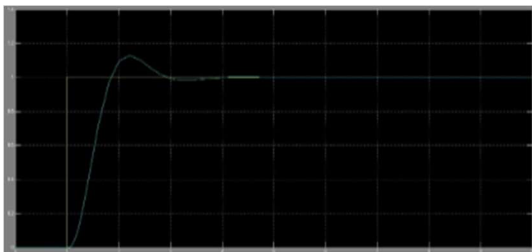

Figure 11. Diagram outcomes of the signals captured by the scope in the MIMO circuit.

The diagram depicts the outcomes of the signals captured by the scope in the MIMO circuit. The waveform is split into two segments, distinguished by yellow and cyan colours. The yellow segment corresponds to the initial signal from the source prior to applying the LQR optimization method. Meanwhile, the cyan segment represents the signal after undergoing the LQR method. It's evident that the

cyan waveform initially surpasses the set point but eventually aligns with it. This suggests suboptimal performance in the communication system.

3.3 Reword LQR in the presence of disturbances

This study will showcase findings from the Matlab Simulink simulation tool, focusing on a system operating amidst noise interference. The goal is to enable a subsequent comparison with motor performance results under similar interference or noise conditions.

3.3.1 Single input, single output

The Simulink software showcases a Single Input-Single Output (SISO) system, characterized by one input/sender and one output/receiver. This configuration is represented in the form of a circuit within the MATLAB Simulink environment.
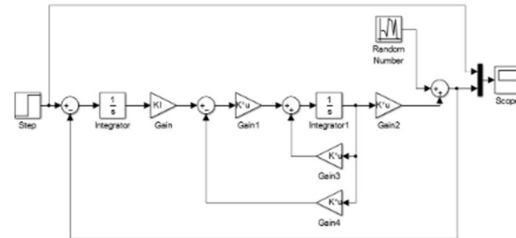

Figure 12. Circuit single input, single output of reword LQR in the presence of disturbances

The image above depicts a circuit configuration, starting with a voltage-input step component on the left. The voltage then progresses to the sum, where one branch captures feedback from the final waveform results, and the other branch leads to the Integrator. Following the Integrator, there's integral control gain, branching into one path with gain B and another path with feedback on the KK gain results. The gain B branch continues to Integrator1, with gain C, and introduces additional noise through a random number before reaching the scope. The original waveform from the step component flows directly to the scope for comparison.

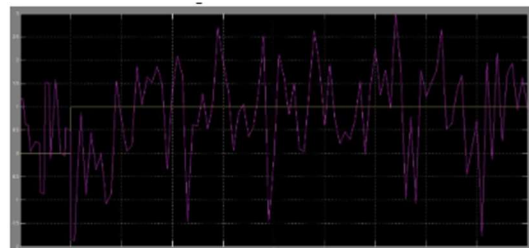The waveform produced by the circuit and simulated using MATLAB Simulink software is described as:

Figure 13. Diagram outcomes of the signals captured by the scope in the SISO circuit utilizing the LQR control approach.

The diagram above depicts the outcomes of the signals captured by the scope in the SISO circuit utilizing the LQR control approach. The signals are represented by two colors, each corresponding to the voltage in the circuit. The original voltage results, untouched by any modifications, are depicted in yellow, showing a sharp spike indicative of the unoptimized original voltage. On the other hand, the purple wave represents the signal outcomes after undergoing the LQR method and being subjected to noise. The yellow wave, originating from the supply without any enhancements, exhibits a pronounced spike due to the lack of optimization. In contrast, the purple wave deviates from the initial setpoint, reflecting the impact of noise despite the optimization efforts through the LQR method.

3.3.2 Single input, multiple output

The SIMO (Single Input-Multiple Output) configuration, characterized by a single sender/input and multiple receivers/outputs, is represented in the Simulink software through a circuit structure, as depicted in the following SIMO circuit within the Matlab Simulink environment.
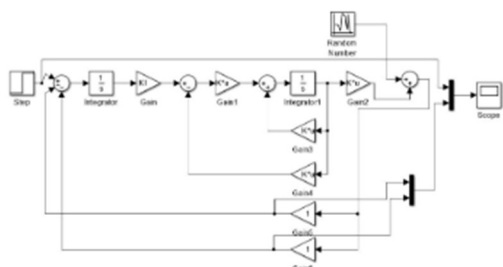

Figure 14. Circuit single input, multiple output of reword LQR in the presence of disturbances

The image displays a circuit configuration, starting with a step component on the left that introduces voltage to the circuit. The voltage then flows through a series of components, with one branch capturing feedback from the final waveform results and another proceeding to the Integrator. Following the Integrator, there is a gain integral control, and the circuit branches again. One branch leads to gain B, while the other receives feedback on the results of gain KK. The gain B branch continues to Integrator1, then to gain C, where a random number is added by the sum. The signal then flows through gain5 and gain6 before reaching the scope. Simultaneously, the original waveform from the step component is directed straight to the scope for comparison.

The waveforms produced by the circuit and simulated using MATLAB Simulink software are described as follows:
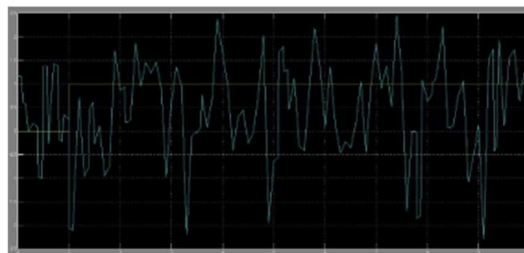

Figure 15. Diagram outcomes of the waves received by the scope in the SIMO circuit employing the LQR control technique.

The diagram above illustrates the outcomes of the waves received by the scope in the SIMO circuit employing the LQR control technique. The waves are depicted in two colours, with each colour symbolizing the voltage circulating within the circuit. The yellow wave represents the unaltered voltage sourced directly from the supply. Conversely, the cyan wave portrays the signal outcomes subsequent to undergoing the LQR method. The yellow wave exhibits a pronounced, spiky shape, indicative of unoptimized voltage derived directly from the source. In contrast, the cyan waveform assumes an irregular shape due to the introduction of noise into the signal. The presence of irregular waves, not aligning with the setpoint, suggests suboptimal performance or unsuitability of the circuit in this communication system.

3.3.3 Multiple input, Single output

The Simulink software illustrates the MISO (Multiple Input-Single Output) system, featuring numerous inputs or senders connected to a single output or receiver within a circuit. The MISO circuit is constructed within the MATLAB Simulink software in the specified manner.
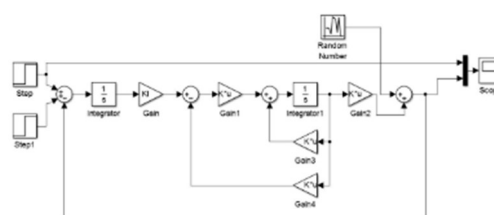

Figure 16. Circuit multiple input, single output of reword LQR in the presence of disturbances

The image displays a circuit configuration with various components. It starts with two step components on the left, drawing voltage into the circuit. The voltage then progresses to a sum, with one branch capturing feedback from the final waveform results, and another branch moving on to the Integrator. Following this, there's gain integral control and branching, where one path leads to gain B and the other receives feedback on the KK gain results. The gain B branch continues to Integrator1 for gain C, incorporating additional noise from a random

number generator before reaching the scope. The original wave from the step component flows directly to the scope for comparison.

The waveform produced by the circuit and simulated using MATLAB Simulink software is outlined below:
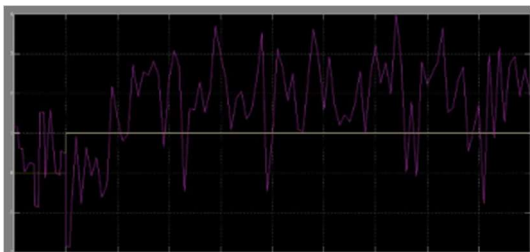

Figure 17. The waveform outcomes for the MISO configuration in Figure

The waveform outcomes for the MISO configuration in Figure 3.14, when subjected to noise, are depicted above. The illustration presents waves captured by the scope within the SISO circuit utilizing the LQR control approach. Two distinct colors represent the voltages in the circuit. The yellow wave portrays the unaltered voltage directly from the source, exhibiting a pronounced and elevated spike due to the absence of optimization. In contrast, the purple wave reflects the signal results post LQR application and noise addition. The purple wave's shape deviates increasingly from the initial setpoint, indicating the impact of added noise despite optimization through the LQR method.

3.3.4 Multiple inputs, multiple output

The Simulink software illustrates a Multiple Input-Multiple Output (MIMO) system, characterized by numerous inputs and outputs. The MIMO circuit is constructed within MATLAB Simulink in the subsequent manner:
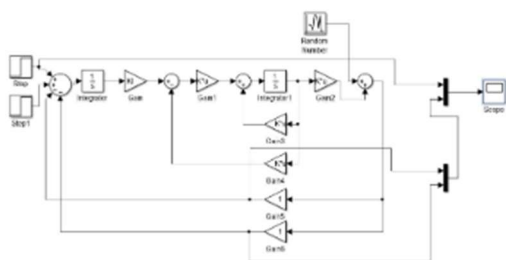

Figure 18. Circuit multiple input, multiple output of reword LQR in the presence of disturbances

The image above depicts a circuit configuration comprising various components. It initiates on the left with two step components drawing voltage into the circuit. The voltage then proceeds to the sum, where one branch captures feedback from the final waveform results, while another continues to the Integrator. Following this, there is integral control for

gain, and the circuit branches again. One branch leads to gain B, and another receives feedback on the outcomes of gain KK. The branch connected to gain B progresses to Integrator 1, followed by gain C, where a random number is added through the sum. This combined signal then flows through gain 5 and gain 6 before reaching the scope. Meanwhile, the original waveform from the step component is directly streamed to the scope for comparison.

The waveforms produced by the circuit and simulated using MATLAB Simulink software are outlined below:
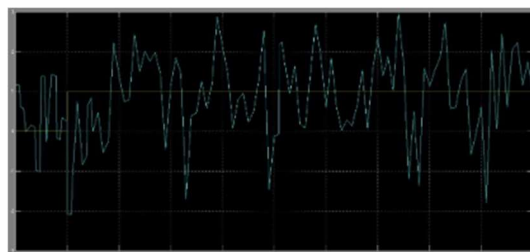

Figure 19. The chart displayed illustrates the outcomes of the signals captured by the scope in the MIMO circuit utilizing the LQR control technique.

The chart displayed illustrates the outcomes of the signals captured by the scope in the MIMO circuit utilizing the LQR control technique. Two distinct colors in the waves signify the voltage within the circuit. The yellow wave indicates the initial voltage directly from the source without any alterations, while the cyan wave represents the signal outcomes following the application of the LQR method. The elevated and pointed spike in the yellow waveform is a result of the unoptimized voltage derived directly from the original source. Meanwhile, the cyan waveform displays an erratic pattern caused by signal interference, and these irregularities, not aligning with the setpoint, indicate that the circuit in this communication system may not be suitable or optimal for use.

4. CONCLUSION

The study produced findings by comparing results, clearly illustrated by the wave image generated using MATLAB Simulink software. The impact of noise on the wave generated by the DC motor, employing the optimal LQR method, is significant. The presence of noise in the signal wave can lead to a deviation in machine performance from the optimal line or setpoint. So, employing the LQR optimal method aims to minimize or alleviate the interference noise. The MIMO system, when coupled with the LQR optimal method, enhances communication. While achieving results near the initial setpoint indicates relatively optimal performance, it may not be flawless.

REFERENCES

[1] Achmad, Irgi, and Anggara Trisna Nugraha. "Implementation of Voltage Stabilizers on Solar Cell System Using Buck-Boost Converter." Journal of Electronics, Electromedical Engineering, and Medical Informatics 4.3 (2022): 154-160.

[2] Nugraha, A. T., Yuniza, S. I., Fathurrohman, M. F., Novsyafantri, Purba, J. V., & Shiddiq, M. J, (2022). PENYEARAH SATU FASE TERKENDALI GLOMBANG PENUH BEBAN RESISTIF. Jurnal Conference on Automation Engineering and Its Application, 2. 46-51

[3] Nugraha, A. T., Yuniza, S. I., Fathurrohman, M. F., Novsyafantri, Purba, J. V., & Shiddiq, M. J, (2022). PENGAPLIKASIAN GENERATOR AC PADA TURBIN UNTUK PENERANGAN SAWAH SAMPING WADUK BERON. Jurnal Conference on Automation Engineering and Its Application, 2. 52-55

[4] Nugraha, A. T., Yuniza, S. I., Fathurrohman, M. F., Novsyafantri, Purba, J. V., & Shiddiq, M. J, (2022). KONTROL LQT UNTUK LEPAS LANDAS DAN PENDARATAN VERTIKAL PADA PESAWAT TANPA AWAK COAXIAL TRIROTOR. Jurnal Conference on Automation Engineering and Its Application, 2. 56-64

[5] Nugraha, A. T., Yuniza, S. I., Fathurrohman, M. F., Novsyafantri, Purba, J. V., & Shiddiq, M. J, (2022). TUNING PARAMETER LINEAR QUADRATIC TRACKINGMENGGUNAKAN ALGORITMA GENETIKA UNTUK PENGENDALIAN GERAK LATERAL QUADCOPTER. Jurnal Conference on Automation Engineering and Its Application, 2. 65-71

[6] Nugraha, Anggara Trisna, Moch Fadhil Ramadhan, and Muhammad Jafar Shiddiq. "Quadcopter Movement Analysis Using Output Feedback Control Based On Line Of Sight." JEEMECS (Journal of Electrical Engineering, Mechatronic and Computer Science) 6.1 (2023): 1-10.

[7] Achmad, Irgi, and Anggara Trisna Nugraha. "Implementasi Buck-Boost Converter pada Hybrid Turbin Angin Savonius dan Panel Surya." Journal of Computer, Electronic, and Telecommunication (COMPLETE) 3.2 (2022).

[8] Shiddiq, Muhammad Jafar, and Anggara Trisna Nugraha. "Sistem Monitoring Detak Jantung pada Sepeda Treadmill." Journal of Computer, Electronic, and Telecommunication (COMPLETE) 3.2 (2022).

[9] Febrianti, Chusnia, and Anggara Trisna Nugraha. "Implementasi Sensor Flowmeter pada Auxiliary Engine Kapal Berbasis Outseal PLC." Journal of Computer, Electronic, and Telecommunication (COMPLETE) 3.2 (2022).

[10] Ivannuri, Fahmi, Anggara Trisna Nugraha, and Lilik Subiyanto. "Prototype Turbin Ventilator Sebagai Pembangkit Listrik Tenaga Angin." Journal of Computer, Electronic, and Telecommunication (COMPLETE) 3.2 (2022).

[11] Nugraha, Anggara Trisna, et al. "The Auxiliary Engine Lubricating Oil Pressure Monitoring System Based on Modbus Communication." Proceedings of the 2nd International Conference on Electronics, Biomedical Engineering, and Health Informatics: ICEBEHI 2021, 3–4 November, Surabaya, Indonesia. Singapore: Springer Nature Singapore, 2022.

[12] Nugraha, Anggara Trisna, et al. "Battery Charger Design in a Renewable Energy Portable Power Plant Based on Arduino Uno R3." Proceedings of the 2nd International Conference on Electronics, Biomedical Engineering, and Health Informatics: ICEBEHI 2021, 3–4 November, Surabaya, Indonesia. Singapore: Springer Nature Singapore, 2022.

[13] Jamil, M. H., et al. "The existence of rice fields in Makassar City." IOP Conference Series: Earth and Environmental Science. Vol. 681. No. 1. IOP Publishing, 2021.

[14] Nugraha, A. T., I. Anshory, and R. Rahim. "Effect of alpha value change on thrust quadcopter Qball-X4 stability testing using backstepping control." IOP Conference Series: Materials Science and Engineering. Vol. 434. IOP Publishing, 2018.

[15] Nugraha, Anggara Trisna, and Trihastuti Agustinah. "Quadcopter path following control design using output feedback with command generator tracker based on LOS." 2017 International Seminar on Intelligent Technology and Its Applications (ISITIA). IEEE, 2017.

[16] Nugraha, A. T., Sa'diyah, A., Indaryani, S., As'ad, R. F., Yuniza, S. I., Agna, D. I. Y., & Shiddiq, M. J. SEPEDA TREADMILL INOVASI DAN DESAIN. Deepublish, 2023.

[17] Nugraha, Anggara Trisna. RANCANG BANGUN TEKNOLOGI PEMURNI AIR. Deepublish, 2022.

[18] Nugraha, A. T., Pambudi, D. S. A., Utomo, A. P., Priyambodo, D., Hari, M. D., & Febrianto, R. RANCANG BANGUN BATERY CHARGER PADA PEMBANGKIT LISTRIK PORTABEL ENERGI TERBARUKAN BERBASIS ARDUINO UNO R3. Deepublish, 2022.

[19] Nugraha, A. T., Widodo, H. A., Pambudi, D. S. A., Cahyono, L., Apriani, M., Utomo, A. P., Priyambodo, D., Putra, M. D. H., & Febrianto, R. "PORTABLE – 2WG" INOVASI TURBIN PEMBANGKIT LISTRIK PORTABLE AIR DAN ANGIN UNTUK KEBUTUHAN RUMAH TANGGA PADA PENDUDUK DAERAH ALIRAN SUNGAI. Deepublish, 2022.

[20] Nugraha, Anggara Trisna, and Rachma Prilian Eviningsih. Konsep Dasar Elektronika Daya.

Deepublish, 2022.

[21] Nugraha, Anggara Trisna, and Rachma Prilian Eviningsih. Penerapan Sistem Elektronika Daya: AC Regulator, DC Chopper, dan Inverter. Deepublish, 2022.

[22] Nugraha, Anggara Trisna, et al. Rancang Bangun Ship Alarm Monitoring (SAM) Sebagai Solusi Keamanan Pengoperasian Auxiliary Engine. Deepublish, 2021.

[23] Sheila, Sindy Yurisma, et al. "Desain and Build a Medium Voltage Cubicel Temperature and Humidity Optimization Tool to Minimize the Occurrence of Corona Disease with the PLC-Based Fuzzy Method." Indonesian Journal of Electronics, Electromedical Engineering, and Medical Informatics 4.4 (2022): 192-198.

[24] AY, Hafizh Ahmad Dzul, Urip Mudjiono, and Anggara Trisna Nugraha. "Rancang Bangun Prototipe Sistem Kontrol Suhu dan Ketinggian Air pada Mesin Extruder." Elektriese: Jurnal Sains dan Teknologi Elektro 12.02 (2022): 117-125.

[25] Zaibah, Siti, Anggara Trisna Nugraha, and Fortunaviaza Habib Ainudin. "Planning a Protection Coordination System Against Over Current Relays and Ground Fault Relays Using the NN Method." Journal of Electronics, Electromedical Engineering, and Medical Informatics 4.4 (2022): 216-222.

[26] Nugraha, Anggara Trisna. "Design and build a distance and heart rate monitoring system on a dynamic bike integrated with power generating system." Journal of Electronics, Electromedical Engineering, and Medical Informatics 4.4 (2022): 210-215.