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Design and implementation of a boost converter circuit based on an Arduino kit

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ABSTRACT

This paper presents a DC motor speed control system based on an Arduino kit with a boost converter that enhances performance under variable load conditions. At load fluctuations, traditional control methods frequently show poor stability and efficiency. A boost converter is used to raise the input voltage to the DC motor. Arduino kit creates a real time pulse with modulation (PWM) signal to modify the duty cycle of the converter and provide dynamic voltage compensation; this system is able to maintain the speed constant in spite of changing with current and torque. The proposed practical connection board offers quicker response time and increases overall efficiency. An economical solution is provided by the combination of boost voltage regulation by Arduino-based PWM control. Results displayed the relationship between torque-speed and torque-current curves with and without the boost unit. Finally, it has been concluded that the boost output voltage is fixed at the desired value.

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1. INTRODUCTION

With the development of technology, direct current (DC) motors are extensively utilized in industrial and domestic applications. However, they frequently encounter speed fluctuations under varying loads, necessitating the use of a controller [1]. In modern electrical engineering applications, the control of DC motors plays a pivotal role in various industrial and consumer systems [2]. The ability to precisely regulate motor speed is essential for enhancing performance, efficiency, and reliability in applications ranging from robotics to automotive systems. Changing the voltage or employing resistive methods are two common ways to manage speed, but they can be wasteful and cause a lot of problems [3].

Power electronics have revolutionized motor control in that it has made possible the accurate, efficient, and flexible control of electrical power supply to the motors. Dynamically controlled voltage and current, which can be achieved through the use of high-power electronic converters, could result in better performance of the motor in terms of torque and speed. In addition, these technologies improve the overall system efficiency and minimize energy wastage as compared to traditional control techniques. Therefore, power electronics has become important in current motor control systems, especially in fields where high performance and flexibility are needed in the face of different operating environments [4], [5].

Recent improvements in power electronics have made it possible to find better solutions, such as boost converters. The torque and speed performance of the motor are improved by a boost converter, which raises the input voltage and permits a higher supply voltage to the motor. When used with a microcontroller like the Arduino, the control system can be both flexible and accurate, letting you make changes in real time based on feedback [6]. The application of a boost converter to regulate a DC motor's speed highlights the benefits of this strategy over traditional techniques [7]. We will examine how boost converters work, how they affect motor performance, and related control techniques that improve system responsiveness and stability [1]. We want to show that this method works for efficient and precise speed control in a range of situations by using simulations and real-world tests.

This project is about making an Arduino-based control system that uses a boost converter to control the speed of a DC motor. With the Arduino and the buck converter, we can monitor and modify it, giving us a control system with a response time fast enough to allow for improved efficiency [8]. The addition of feedback mechanisms and the like, such as pulse width modulation (PWM), is to allow for finer adjustment of the speed of the motor and, by doing so, results in higher efficiency and better function [9].

In this project, we will learn about the boost converter, its construction and operation, programming the Arduino controller, and combining all these items to provide us with effective motor speed control [10]. We expect our results to underscore the benefits of this method in a number of applications, attesting to a flexible and powerful technique for current motor control.

2. LITERATURE REVIEW

Control of the speed of DC motors has been a topic of thorough investigation during the last several decades because of an extensive scope of its applications in robotics, electric cars, industrial automation, and other electromechanical systems. Researchers have come up with a myriad of control measures that focus on enhancing performance, accuracy, and energy consumption under varying operating conditions. These methods consist of both classical control techniques and current ones that involve the use of power electronics and intelligent control algorithms. Consequently, DC motor speed control continues to be a dynamic and significant field of study in the field of electrical engineering.

In 2024, Rathi and Aspalli [11] proposed a model and simulated the boost converter with Arduino using two push buttons; the presented work is an open-loop model with minimized hardware, high performance, less weight, and accuracy. Arduino allows for simple regulation of DC output voltage, despite lower power consumption compared to complex hardware circuits. In 2021, Ma’arif and Setiawan [6] focused on controlling a DC motor based on integral state feedback through simulation software and hardware implementation. Results showed good performance in reaching set points and tracking control, with fast rise and settling times. The research also showed better system response in tracking control compared to PID controllers. Future research includes determining controller parameters, overcoming the challenge of all states being known, and applying Kalman filters to minimize oscillation and noise in output sensors.

In 2023, Rikwan and Ma’arif [10] studied the controller for DC motor angular velocity using the Arduino UNO-based PID method, which was tested, and concluded that the correct PID value can be obtained by changing KP, KI, and KD values according to the trial-and-error method. The system response was obtained from the tested parameters, with rise time = 0.9925, settling time = 2.7368, overshoot = 1.3333, and steady-state error = 0. In 2023, Sulakhe *et al.* [12] analyzed the DC motor speed control using a chopper and a proportional-integral-type speed and current controller. The model is adapted to change load conditions, input voltage, and reference speed conditions, and the results are analyzed for rated and under-rated speeds. This project is developed based on earlier works by incorporating PWM-based control with an Arduino platform, voltage control with a boost converter, and speed control with a feedback-based system to enable efficient control of a DC motor. These techniques together enable the fine control of the motor speed in a variety of load conditions, with the PWM signal dynamically changing the duty cycle to adjust the output voltage of the converter. Moreover, the feedback mechanism helps to increase the stability of the system and make sure that the motor has a rather constant speed in spite of disturbances like load or torque changes. Thus, the suggested solution is a cost-efficient and sustainable solution that will enhance the performance and energy efficiency over the conventional control solutions.

3. METHOD

DC motors are utilized extensively in robotics, electric cars, industrial automation, and domestic applications, making speed control an essential subject in electrical engineering. Their ease of control, excellent efficiency, and predictable torque–speed characteristics all make them so popular. However, because of voltage drops and variations in torque requirements, the motor speed tends to fluctuate under different load circumstances. Thus, to ensure consistent performance, strong and adaptable control mechanisms are needed.

3.1. DC motor modelling

The armature winding of a SEDCM is powered by an external source, whereas the field winding receives current directly from the armature [13]. The corresponding equivalent circuit is shown in Figure 1.

This configuration implies that the armature and field currents are independent. During operation, the armature current induces a back electromotive force (back-EMF) opposing the supply current [14]. The motor continues to rotate until the applied voltage and the back-EMF balance each other, at which point the developed torque equals the load torque.

The armature winding is provided with current from an external supply, while the field winding is supplied with current from the armature winding itself. This indicates that there is no relationship between the armature current and the field current [15]. When the motor is running, the armature current creates a back electromotive force (BEMF) that opposes the current flowing through the armature winding [16]. The motor will keep turning until the applied voltage and the back EMF are equal. At this point, the motor will produce a torque that is equal to the load torque [17], [18]. The armature current will always be greater than the field current because the armature winding has a higher resistance than the field winding. This is why separately excited DC motors are often used in applications where precise speed control is required [9]. The fundamental motor equations are:

$$V_a = R_a I_a + L_a \frac{dI_a}{dt} + E_b \tag{1}$$

$$T_d = J\frac{d\omega}{dt} + T_L + B\omega \tag{2}$$

The motor's back emf can also be expressed as (3).

$$E_b = K_a\, \varphi\omega \tag{3}$$

Also,

$$T_d = K_a\, \varphi I_a \tag{4}$$

where V_a is the armature voltage (V); I_a is the armature current (A); R_a is the armature resistance (Ω); L_a is the armature inductance (H); E_b is the back electromotive force (V); T_L is the load torque (N.m); T_d is the developed torque (N.m); J is the moment of inertia (kg·m²); B is the motor friction coefficient, ω is the angular velocity (rad/s); and φ is the developed magnetic flux (Wb). Under steady-state conditions, the armature inductance term can be neglected, and the angular velocity is therefore expressed as (5).

$$\omega = \frac{V_a - R_a I_a}{K_a\, \varphi} \tag{5}$$

Thus, using the aforementioned (5), the DC motor's speed may be controlled by adjusting the armature voltage and field flux. Among the three techniques for regulating a DC motor's speed, the armature enables a seamless changeover from zero to base speed [19]. At the rated voltage of the supply, the speed attained is known as the base speed. The (2) becomes (6) if we assume that the motor's friction is negligible (B=0).

$$T_d = J\frac{d\omega}{dt} + T_L \tag{6}$$

The (6)-(9) are obtained by applying the Laplace transform to the previously stated (7)-(9):

$$I_a(s) = \frac{V_a - E_b}{R_a + L_a * s} \tag{7}$$

$$I_a(s) = \frac{V_a - K_a\, \varphi\omega}{R_a\left(1 + S\frac{L_a}{R_a}\right)} = \frac{V_a - K_a\, \varphi\omega}{R_a(1 + ST_a)} \tag{8}$$

$$\omega(s) = \frac{T_d - T_L}{J_s} = \frac{K_a\, \varphi I_a - T_L}{J_s} \tag{9}$$

where $T_a = \frac{La}{R}$.

The block diagram of the DC motor model is illustrated in Figure 2. The transfer function that results from carrying out the block reduction will have the following structure.

$$\frac{\omega(s)}{V_a(s)} = \frac{\frac{k_a\varphi/R_a}{J_s(1+sT_a)}}{1+\frac{K_a^2\varphi^2}{J_s(1+sT_a)}} = \frac{1/k_a\varphi}{sT_m\,(1+sT_a)+1} \tag{10}$$

Assuming $T_m = \frac{J_s R_a}{(K_a \varphi)^2}$ and replacing $K_a \varphi = K_m$, (10) can be reduced to (11).

$$\frac{\omega(s)}{V_a(s)} = \frac{\frac{1}{K_m}}{(1+sT_m)(1+sT_a)} \tag{11}$$

As a result, for the system mentioned above, T_m and T_a stand for the time constants used in the transfer function. The system's overall reaction will be impacted by these temporal constants [20]. Therefore, the transfer function obtained in (11) within the model can be used in place of the DC motor [21]. The Terco DC motor utilized in the simulation in this paper has the parameters listed in Table 1.

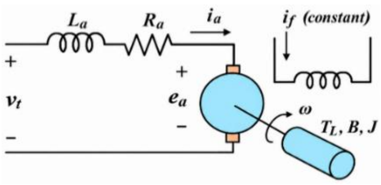

Figure 1. Equivalent circuit of a SEDCM

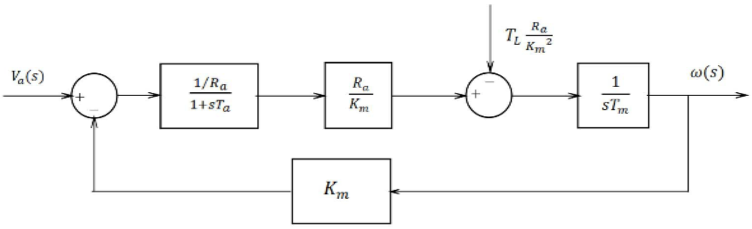

Figure 2. DC motor model

Table 1. Description of Terco DC motor

Parameters	Standards	Parameters	Standards
Aaaaa	1.00111	Jm	0.012 kg.m^2
Bbbbb	11.123	Bm	0.0204 N.m.s .rad^{-1}
Ra	0.25 Ω	Kb	10 V.s.rad^{-1}
La	60.81 mH	Rated speed	m

3.2. PWM

PWM controls DC motor speed by varying the duty cycle from (0% to 100%) to alter the effective voltage. Managed by microcontrollers and MOSFETs, this method ensures Precise movement, higher efficiency, and reduced Power loss. It is necessary to note that attention should be paid to the clock frequency of the PWM signal. Typically, motors have specifications under which they need to be operated. For motors, speed control should be at least 1 kHz or higher in frequency. Power losses increase as the frequency decreases. However, modern power MOSFETs are already suitable encapsulated packages, given this requirement.

3.3. PWM frequency and duty cycle impact on system performance

Switching frequency is a balance between efficiency and performance. Higher frequencies improve motor Stability and reduce ripples, but increase switching losses and EMI. Conversely, lower frequency is generally required where reduced switching frequencies are less Prone to switching losses and more efficient, but generate higher voltage ripple and current variations, which can adversely affect the motor Performance and add unwanted oscillations [22].

3.4. A boost converter

A boost converter is a DC-DC power electronic converter, which is a step-up chopper, and is made to raise the input voltage to a maximum output voltage level. It accomplishes this role by storing energy in an inductor and a switching action that is regulated, facilitating the conversion of voltages effectively. This is the reason why boost converters are especially appropriate in applications that need more output voltage than the available input supply, such as DC motor control systems [21]. Figure 3 illustrates the circuit diagram of the boost converter.

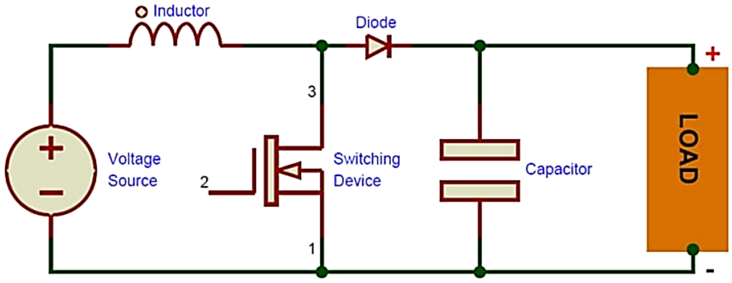

Figure 3. Boost converter circuit diagram

3.4.1. Mathematical modeling of boost converter

Mathematical modeling of a boost converter is a fundamental area of power electronics, stipulating how a DC-DC converter can effectively boost a source voltage to a higher output voltage. The boost converter is a non-linear system that regulates the flow of energy using an inductor and a high-speed switch (MOSFET/IGBT). Based on the inductor volt-second balance principle, energy is stored in the inductor during the ON state and transferred to the load during the OFF state. This process is mathematically controlled by the duty cycle (D), which determines the switch's conduction time [23]. The inductor current ripple is an important parameter affecting converter performance and is expressed as (12):

$$\Delta I_L = \frac{V_{in} \cdot D}{L \cdot f_s} \tag{12}$$

where ΔI_L is the inductor current ripple; L is the inductance; and f_s is the switching frequency.

A properly selected inductor ensures continuous conduction and reduces current ripple, which improves system stability. The output voltage ripple depends on the capacitor value and load current and is given by (13):

$$\Delta V_o = \frac{I_o \cdot D}{C \cdot f_s} \tag{13}$$

where ΔV_o is the output voltage ripple; I_o is the output current; and C is the capacitance.

Minimizing voltage ripple is essential for maintaining a stable motor speed. Switching losses occur in the power MOSFET during the transition between the on and off states. A common linear approximation for the total switching loss P is:

$$p_{sw} = \frac{1}{2} . v_{out} . I_L . (t_r + t_f) . f_s \tag{14}$$

where V_{out} is the voltage across the switch when off; and I_L is the current through the switch when on. Boost converter components were selected based on worst-case operating conditions and experimental data. Calculating ratings included safety margins to ensure system stability, as detailed in Table 2.

Table 2. Ratings of boost converter components

Component	Calculated requirement	Selected rating
Inductor	650 µH, $I_{sat} \geq 19.5$ A	650 µH/20 A
Capacitor	C ≥ 40.4 µF, V ≥ 317.25 V	100 µF/400 V, low ESR
Diode	V ≥ 317.25 V, I ≥ 13.44 A	400 V/15-20 A fast recovery
MOSFET/IGBT	V ≥ 317.25 V, I ≥ 26 A	400-500 V/30 A

3.5. Arduino UNO overview

Arduino-based speed control of a DC motor with Arduino UNO [24]. For Arduino-based speed control, the desired speed is compared with the motor speed measured through a tachometer, and the difference is used as an input to control the armature voltage of the DC motor, which indirectly controls the motor speed. The output voltage provided to the motor is controlled by using a boost converter [25]. The circuit of the proposed work is simulated and tested for both closed-loop and open-loop systems for analysis and performance comparison.

The Arduino UNO board is designed to make the process of using microcontrollers by students or professionals as easy as possible [26]. It is equipped with an Atmega328 microcontroller that operates at 5 V.

It has 32-kB flash memory and 14 digital input/output pins. The major components of the Arduino UNO are the main input port pin, USB end port, DC power input port, analog input pins, the analog input pins convert up to 0-5 V, DC input pins, LCD inputs, and buzzer output pin. The detailed pin descriptions are mentioned in the text. The block diagram of the Arduino UNO board is shown in the text. I/O PIN BOARD: 7-bit port, 4-bit port, 7-bit port. Figure 4 illustrates the Arduino kit.

Figure 4. Arduino UNO kit

3.6. Integration of boost converter with DC motor

The boost converter utilizes an inductor, capacitor, and a diode controlled by an Arduino PWM signal via on IG ST switch to regulate voltage. By adjusting the duty cycle, the system manages power flow to the DC motor, using a free-wheeling diode to maintain current and prevent back EMF issues during the Switch's "OFF" periods. Figure 5 shows the flowchart of DC motor speed control based on Arduino, which describes the interplay between the important parts, such as the reference input, comparator, Arduino-based controller, boost converter, DC power source, and the motor with its feedback loop. The figure gives a good illustration of the signal flow and power transfer in the system and how the controller modulates the converter duty cycle to ensure the motor runs at the desired speed in varying operating conditions.

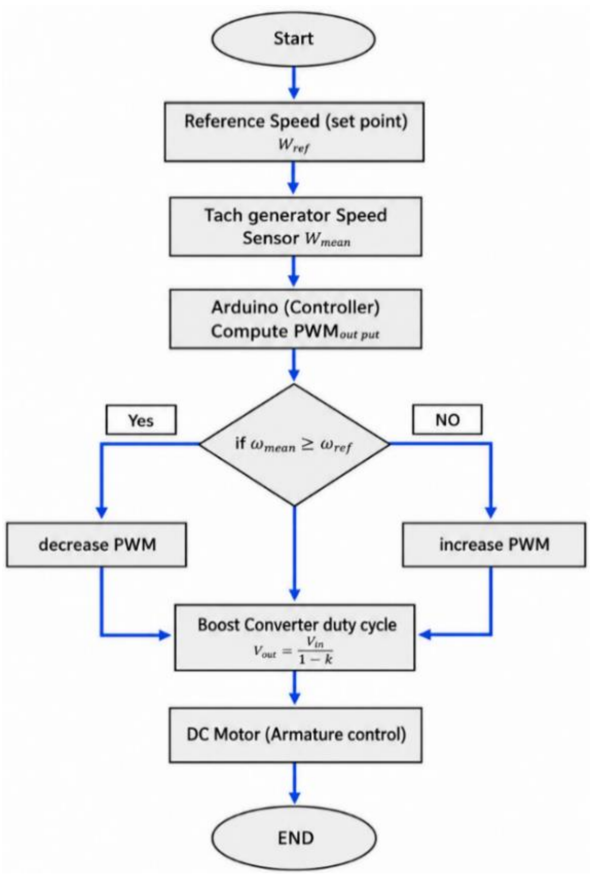

Figure 5. Flowchart of DC motor speed control using boost converter and Arduino

4. RESULTS AND DISCUSSION

An experimental prototype was created and put through laboratory testing in order to arrive at the suggested control technique. The prototype design includes a separately excited DC motor linked to a DC generator that acts as a controlled load. To supply electricity to the motor, a boost converter is used, and an Arduino UNO microcontroller uses PWM to regulate the output voltage. The motor shaft is equipped with a tach generator, which gives the control system real-time speed feedback. Figure 6 provides an image of the total system.

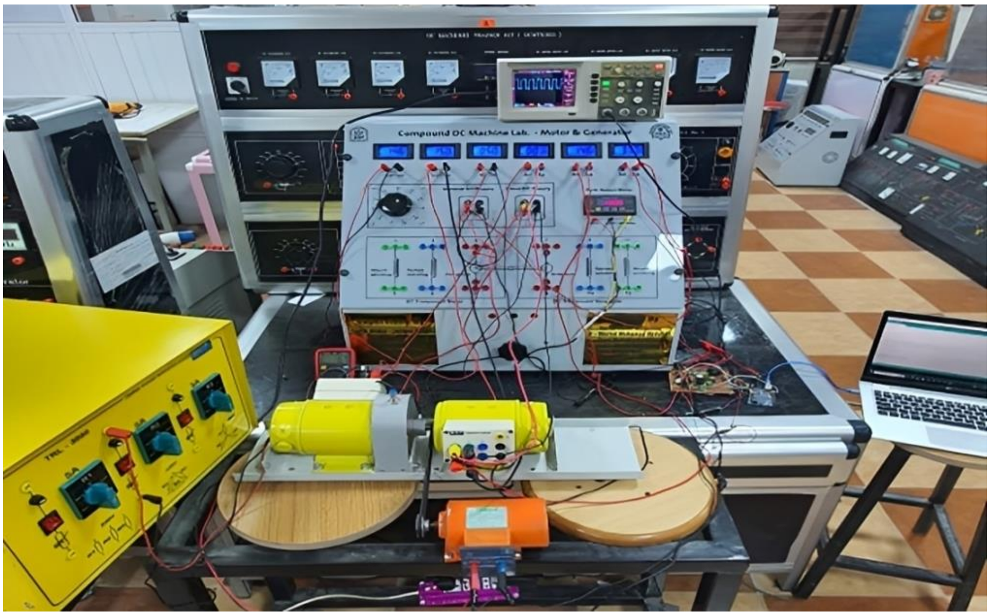

Figure 6. Practical board

The resistance in the generator's circuit the load was changed. Next, the boost converter was inserted between the power supply and the motor. PWM signals were produced by the Arduino UNO to regulate the duty cycle of the converter. In order to compensate for any speed variation brought on by variations in load, the Arduino continuously read the tach generator signal, compared it to the reference speed, and modified the duty cycle. Data has been collected for the two open-loop (without boost) and closed-loop (with boost) configurations. A closed-loop method was used to achieve this.

The experimental design involves two separately excited DC motors coupled together mechanically with a DC generator, which is a controllable load. The system also has a tach generator to provide speed feedback, a boost converter to provide voltage regulation, and an Arduino-based control unit to produce PWM signals. Moreover, measurement devices and a voltage divider feedback circuit are also provided to check the performance of the system and to control it accurately. Such a combined setup allows assessing the offered strategy of motor speed regulation in different operating conditions effectively.

4.1. Experimental procedure

On the same shaft, the generator and motor were fixedly connected. To determine a baseline reaction, the motor supply was initially connected directly without the boost converter. Under various load scenarios, measurements were made of speed, armature current, torque (derived from generator load), and supply voltage. By adjusting the resistance in the generator's circuit, the load was changed. Next, the boost converter was inserted between the power supply and the motor. PWM signals were produced by the Arduino UNO to regulate the duty cycle of the converter. In order to compensate for any speed variation brought on by variations in load, the Arduino continuously read the tach generator signal, compared it to the reference speed, and modified the duty cycle.

Data has been collected for the two open-loop (without boost) and closed-loop (with boost) configurations. A closed-loop method was used to achieve this. This board consists of a separately excited DC motor coupled with a DC generator, a tach generator, a boost converter, double voltage divider feedback, Arduino kit, and measurement meters. Table 3 represents the practical readings.

Table 3. Lab practical readings

V_{in} (V) (Boost)	V_{out} (V) (Boost)	I_{in} (A) (Boost)	I_{out} (A) (Boost)	N (rpm)	T (N·m)
100	200	1.8	0.8	1500	0.25
98	203	2.9	1.23	1500	0.8
97.5	204	4	1.7	1500	1.5
97	205	5.2	2.2	1500	2.1
96	206	6.4	2.7	1500	2.8
95	207	7.4	3.7	1500	3.4
94.5	209	8.5	3.1	1500	4
94.2	210	9.6	3.5	1500	4.6
94	210.5	10.8	4	1500	5.2
88.8	211	12	4.5	1500	5.8
84	211.5	13	6.7	1500	6.2

The proposed boost converter was considered, and its efficiency was assessed based on the experimental scores represented in Table 3, where the input and output voltages and currents were measured at various load torque configurations. According to these measurements, the input power P_{in}, output power P_{out} and efficiency η were determined based on (15)-(17).

$$P_{in} = V_{in} \cdot I_{in} \tag{15}$$

$$P_{out} = V_o \cdot I_o \tag{16}$$

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \tag{17}$$

Table 4 summarizes the calculated efficiency values. As illustrated in the comparison between Table 2 and Table 3, the input power rises with load torque because of the higher current required by the DC motor, and the output power also rises to ensure that the speed of the motor remains at a constant value of 1500 rpm.

Depending on Table 4, it can be seen that converter efficiency lies in the vicinity of 87.8 to 94.3, which implies that it can operate efficiently under diverse load conditions. The efficiency trend is gradually on the rise with increasing load torque. This can be attributed to the fact that, even though the conduction losses increase as the current increases, the ratio of the useful output power to the total input power increases. Contrastingly, switching losses are constant at a given PWM frequency, leading to increased overall efficiency at higher loads. Furthermore, the difference between input and output power in Table 3 represents the total power losses:

$$P_{loss} = P_{in} - P_{out} \tag{18}$$

These losses are the conduction losses of the semiconductor devices and passive components, and switching losses during the turn-off and turn-on of the switching device. The results of the comparison between Tables 3 and 4 clearly show that the proposed boost converter is able to convert power efficiently and keep the motor running at the same load under varying load torque conditions. Table 4 summarizes the calculated efficiency values.

Table 4. Performance analysis values under varying load

Torque (N.m)	P_{in} (W)	P_{out} (W)	Efficiency (%)	Torque (N.m)	P_{in} (W)	P_{out} (W)	Efficiency (%)
0.25	180.00	180.00	100.00	4.00	803.25	898.70	111.88
0.80	284.20	284.20	100.00	4.60	904.32	1018.50	112.63
1.50	390.00	408.00	104.62	5.20	1015.20	1147.23	113.01
2.10	504.40	533.00	105.67	5.80	1065.60	1266.00	118.81
2.80	614.40	659.20	107.29	6.20	1092.00	1374.75	125.89
3.40	703.00	765.90	108.95				

Figure 7 shows the change in converter efficiency with load torque. One can notice that the efficiency increases slowly with the increase in the load torque, with values of about 87.8% when the load torque is lower and 94.3% when the load torque is higher. This tendency implies better utilization of input power at higher operating conditions (where the proportionate contribution of switching losses is less important than the output power).

In this section, the results of experimental testing of a proposed speed control of a DC motor are presented and discussed. This analysis compares the performance of the standard setup (without a boost converter) with the enhanced system (with a boost converter) under varied load and supply Conditions. Figures 7 to 16 show how important mechanical and electrical factors, such as torque, speed, current, and voltage, relate to one another.

From Figure 7, notice that the efficiency increases slowly with the increase of the load torque, with values of about 87.8%. When the load torque is low and 94.3%. When the load torque is high, Figure 8 showed that the velocity of the motor gradually drops while the load torque rises. Figure 9 displayed that the speed remains constant even as torque rises.

Figure 10 illustrated that the armature current increases as the torque increases also, but without using the boost, bout cased the motor speed fell as a result of voltage drops. Figure 11 gave similar behavior between torque and armature current as Figure 10, but the motor speed remained constant despite changes in the torque and better speed regulation than the non-boost case. Figure 12 shows a small overshoot and quickly settles, which means that the behavior is stable and well-damped.

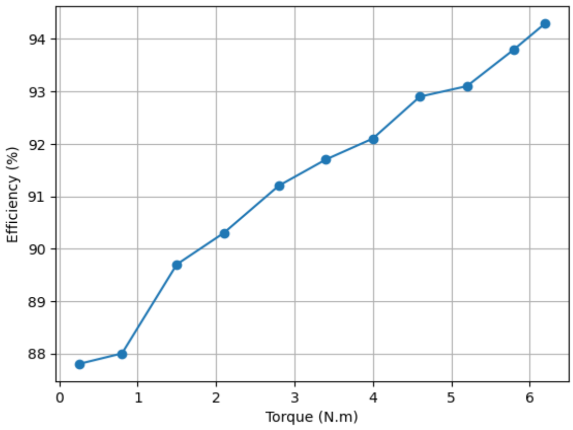

Figure 7. Converter efficiency V-S source

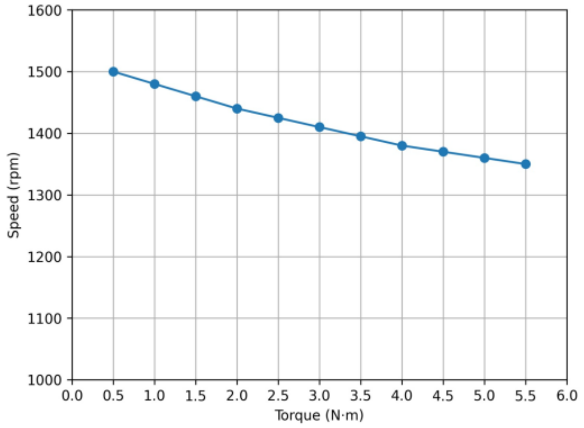

Figure 8. Torque–speed characteristic of DC motor

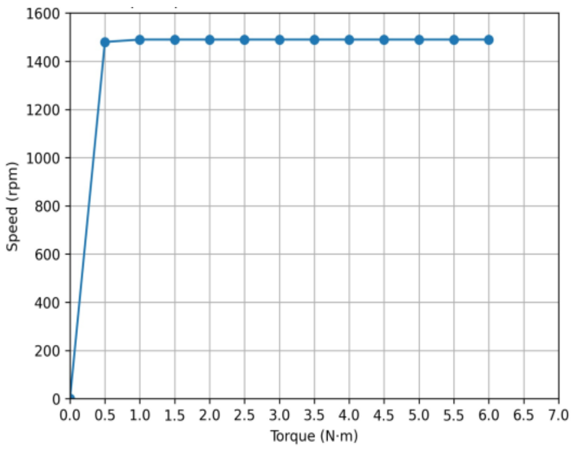

Figure 9. Torque-speed curve with boost

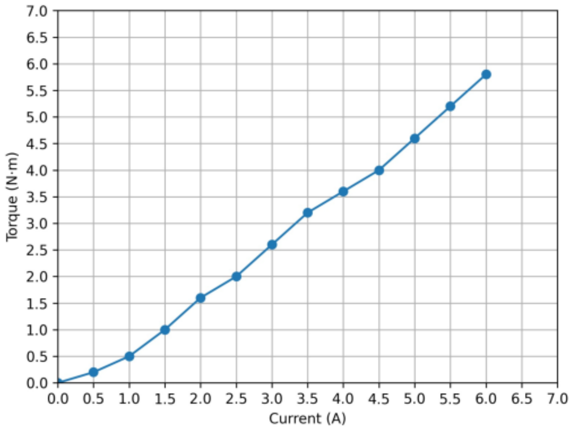

Figure 10. Torque-current without boost

Figure 13 shows the speed reduction occurred due to the relationship in the electromagnetic torque as a result of the lack of voltage compensation during loading without using the boost. Figure 14, the speed remains constant with respect to an increase in load when using the boost. From Figure 15, with the absence of the boost converter, the motor speed reduced proportionately with respect to the decrease in supplied voltage, but the speed remained constant at boost voltage 203 V, as shown in Figure 16.

The Arduino control system can be used in low- to medium-power systems because of its simplicity and affordability. Nevertheless, its power is restricted by processing power, resolution of PWM output, and current limiting in its ability to drive high-power industrial motors. More advanced controllers like DSPs or industrial-grade microcontrollers are needed to facilitate scalability to industrial applications and sturdy power electronic components and suitable thermal and protection systems.

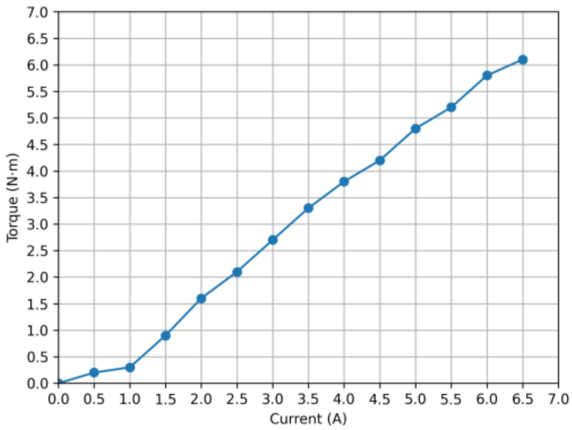

Figure 11. Current-torque with boost

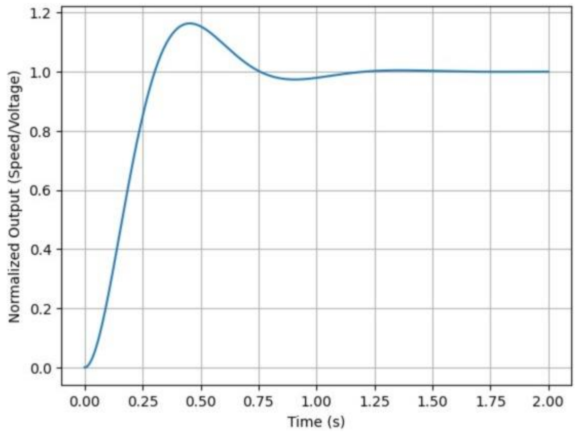

Figure 12. Dynamic response of the system under sudden load change

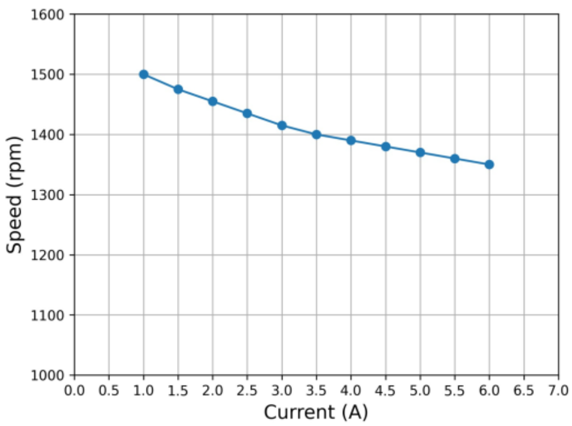

Figure 13. Current-speed curve without boost

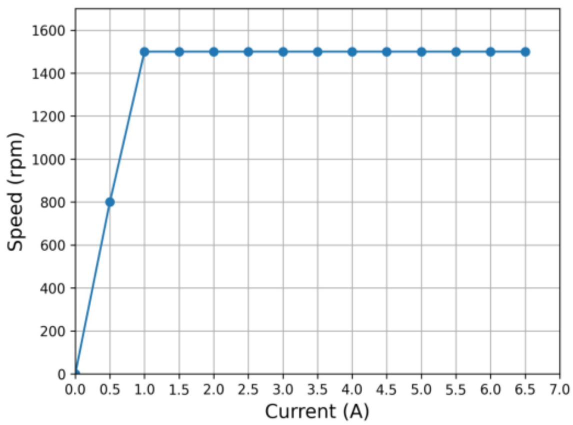

Figure 14. Current–speed curve under boost mode

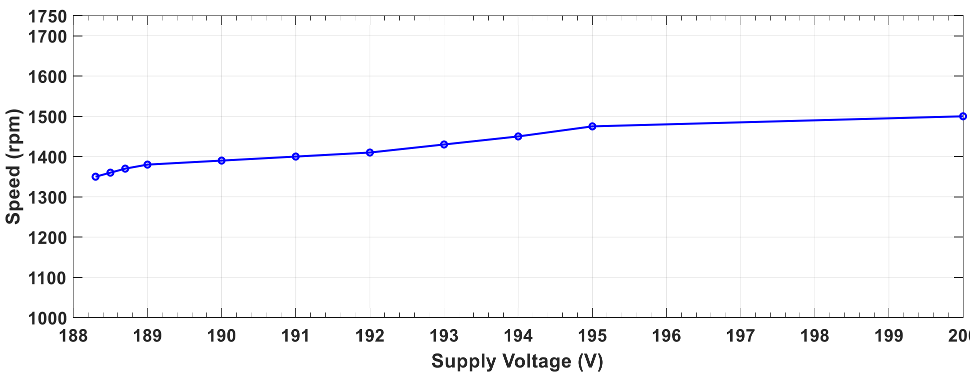

Figure 15. Supply voltage-speed curve without boost

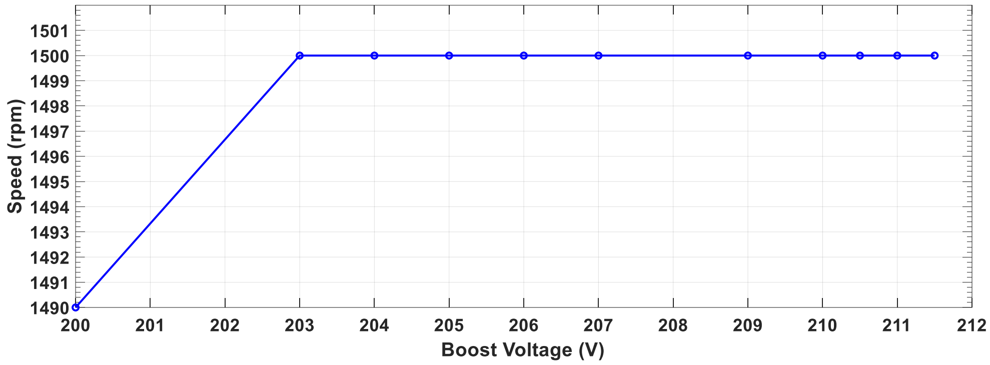

Figure 16. Boost voltage-speed curve

The proposed system is sensitive to the manner in which it responds to non-ideal operating conditions, thereby affecting the reliability of the system. The voltage regulation loss can cause speed instability in case of a boost converter fault. On the same note, excessive current and thermal stress can be triggered by motor overload, and the closed-loop control can be disrupted by the failure of the feedback sensor, leading to inaccurate regulation of the speed. Thus, it is important to use protection systems like overcurrent protection, fault detection, and effective sensing systems to make the systems stable and reliable in their operation.

This work is unique because it combines an Arduino-based PWM control with a boost converter into a closed-loop system and dynamic voltage compensation of the system under different load conditions. In contrast to traditional methods, the suggested method improves the stability of torque and speed, and the response of the system with real-time feedback control. Moreover, the experiment in the study shows the performance enhancement in contrast to the non-boost operation, which indicates the practical and efficient implementation.

5. CONCLUSIONS

This paper has detailed the design, implementation, and performance evaluation of a DC motor speed control system which uses an Arduino controller with a boost converter. The given system successfully addresses the shortcomings of conventional control techniques, especially in variable load situations, by increasing the voltage applied, as well as improving the dynamic response. The experimental results indicate that the system is capable of sustaining constant motor speed even when there are high torque and current changes. Speed regulation of DC motors using a combination of a boost converter and PWM-based control is an efficient, reliable, and cost-effective solution. Moreover, the real-world application of theoretical models is justified by the presence of the hardware implementation, which proves the feasibility of the suggested approach in actual applications.

The study demonstrates that integrating a boost converter with Arduino-based PWM control significantly improves system stability and torque-speed profiles by compensating for voltage drops. This approach enhances energy efficiency and ensures a fast, reliable response to load changes, as validated by hardware implementation. Future research will focus on refining control strategies through PID or adaptive methods, scaling for higher power applications, and incorporating IoT-based monitoring for remote diagnostics.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
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Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial, financial, or institutional relationship that could be construed as a potential conflict of interest. All findings, interpretations, and conclusions presented in this study are based purely on scientific merit, empirical rigor, and objective analysis, ensuring absolute integrity and impartiality in the research outcome.

DATA AVAILABILITY

The data supporting the findings of this study are available within the article. Additional simulation models, source codes, and experimental datasets generated during this study are available from the corresponding author upon reasonable request, ensuring complete transparency and reproducibility of the research outcome.

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