**IAES Journal of Electrical and Electronics Engineering**
Vol. 12, No. 2, December 2025, pp. 53~58
ISSN: 2338-7432, DOI: 10.11591/jeee.v12i2.pp53-58 

# Electrification of conventional lawn mowers: a review of powertrain conversion, battery management, and intelligent motor control

**Sajad Abdollahzadeh Anbaran**
Power Electronics and Drives Research Group, Universiti Teknologi Malaysia, Johor Bahru, Malaysia

**Article Info**

***Article history:***

Received Sep 28, 2023
Revised Jan 2, 2025
Accepted Jan 28, 2025

***Keywords:***

Adaptive motor control
Battery management system
Direct torque control
Electric lawn mower
Field-oriented control
Powertrain conversion
Thermal protection

**ABSTRACT**

The electrification of conventional gasoline-powered lawn mowers offers an opportunity to reduce local emissions, operating noise, fuel consumption, and maintenance requirements. However, replacing an internal combustion engine with an electric motor requires more than a simple component substitution because mowing involves variable mechanical loads, blade-speed requirements, vibration, and exposure to dust and moisture. This review examines the engineering principles of lawn mower electrification, focusing on powertrain architecture, mechanical and electrical conversion, battery management systems, and intelligent motor control. Particular attention is given to field-oriented control (FOC), direct torque control (DTC), adaptive speed regulation according to grass density and height, and motor protection against overload and overheating. Relevant findings from lawn mower engineering, electric vehicle powertrains, battery technologies, and electric motor drives are critically synthesized to identify transferable design principles and application-specific limitations. The review indicates that a coordinated battery–inverter–motor architecture, supported by load-responsive control and integrated thermal protection, is essential for reliable operation. It also identifies the need for standardized field testing under different grass conditions to validate energy consumption, cutting performance, and system durability.

*This is an open access article under the CC BY-SA license.*

***Corresponding Author:***

Sajad Abdollahzadeh Anbaran
Power Electronics and Drives Research Group, Universiti Teknologi Malaysia
Johor Bahru, Malaysia
Email: sajjad.abdollah@gmail.com

## 1. INTRODUCTION

Conventional gasoline-powered lawn mowers remain widely used because their engines provide relatively high power, rapid refuelling, and operational flexibility. Nevertheless, internal combustion engines produce exhaust emissions, generate considerable noise, require periodic maintenance, and depend on fossil fuels. Electric alternatives can reduce several of these disadvantages by replacing the combustion engine with an electrically driven cutting system and, where required, an independent propulsion motor. The transition is particularly relevant for residential areas, parks, campuses, and other locations where noise and local air quality are important considerations [1], [2].

The electrification of a lawn mower presents engineering challenges that differ from those of many conventional electric vehicles. A mower blade experiences rapidly changing resistance as it encounters variations in grass density, moisture, height, and cutting conditions. These variations produce transient torque demands that can cause speed reduction, increased current, and motor heating if the drive is not appropriately

controlled. Consequently, an effective conversion requires coordinated mechanical design, electrical power management, battery protection, and adaptive motor control rather than an isolated motor replacement [3], [4].

Although research on electric powertrains and battery management has advanced considerably, application-specific integration for converted lawn mowers remains insufficiently documented. Existing electric vehicle studies provide useful knowledge about motor selection, inverter design, battery monitoring, and advanced control, but their operating conditions cannot be transferred directly without considering the mower's cutting load. This review therefore evaluates how established electrical engineering methods can be adapted to conventional lawn mower conversion. Its main contribution is an integrated framework connecting powertrain architecture, battery management, load-responsive speed control, and motor protection to the practical requirements of grass cutting.

## 2. ELECTRIC POWERTRAIN ARCHITECTURE AND CONVERSION

### 2.1. Proposed powertrain architecture

An electric lawn mower powertrain typically consists of a battery pack, battery management system (BMS), motor controller, power inverter or electronic drive, electric motor, and mechanical transmission to the cutting blade. A self-propelled mower may require an additional drive motor for the wheels, whereas a walk-behind push mower generally needs only the blade motor. The electrical system should also include a low-voltage control supply, operator interface, emergency stop, and safety interlocks. This arrangement follows the general integration principles established in electric vehicle powertrain research, although its voltage, power, and packaging requirements are generally different [1], [3], [5].

The architecture can be implemented using either a single-motor or dual-motor configuration. A single motor can drive the blade and, through an appropriate transmission, provide propulsion, but this arrangement complicates independent speed regulation and mechanical optimization. A dual-motor configuration separates blade rotation from wheel propulsion, allowing each motor to operate according to its own load and speed requirements. This separation is particularly attractive for self-propelled mowers because propulsion demand does not necessarily increase when grass-cutting resistance rises [2], [6].

### 2.2. Mechanical and electrical conversion

Mechanical conversion begins with the removal of the gasoline engine and the assessment of the existing blade shaft, mounting frame, bearings, belt, pulleys, and transmission components. The replacement motor must provide adequate torque and rotational speed while remaining compatible with the available installation space and structural strength. Direct coupling can reduce transmission losses and simplify the mechanical arrangement, whereas belt or gear transmission can provide speed adaptation and isolate some mechanical vibration. The selection should consider blade inertia, shaft alignment, bearing loads, blade balance, and the possibility of debris entering the drive assembly.

Electrical conversion requires the integration of a battery pack, motor controller, inverter, wiring harness, protective devices, and charging interface. A brushless DC motor or permanent magnet synchronous motor (PMSM) is a practical option because of its high power density and controllability, while an induction motor may be considered where robustness and reduced dependence on permanent magnets are priorities [1], [7]. The inverter must be rated for the motor's continuous and transient current requirements, particularly during blade acceleration and sudden increases in cutting resistance. Power semiconductor selection, switching losses, electromagnetic compatibility, and heat dissipation should therefore be evaluated together rather than as separate design decisions [8].

A conversion project should also retain or improve the original mower's mechanical safety features. The blade enclosure, operator-presence control, emergency stopping mechanism, and protection against accidental blade activation must remain functional after conversion. Battery placement should preserve structural balance and avoid excessive loading of the mower frame. The resulting system should be inspected for vibration, water ingress, cable abrasion, and the possibility of mechanical interference between the blade, motor, and protective housing.

## 3. BATTERY TECHNOLOGY AND BATTERY MANAGEMENT

### 3.1. Battery selection and sizing

Battery selection determines the mower's operating duration, available power, mass, cost, and charging requirements. Lithium-ion batteries are attractive because of their relatively high energy density, rechargeability, and suitability for portable equipment, although the appropriate chemistry depends on the required balance between energy density, cost, safety, and cycle life. Lithium iron phosphate (LFP), for example, can be considered where thermal stability and durability are prioritized, while other lithium-ion

chemistries may offer higher energy density. Battery capacity should be selected using measured energy consumption under realistic cutting conditions rather than nominal motor power alone [9], [10].

Battery sizing must account for both continuous and transient power demands. The blade motor may require substantial current during acceleration or when cutting dense grass, while the propulsion motor introduces an additional demand in self-propelled models. A battery with adequate energy capacity may still be unsuitable if its discharge-current capability or voltage stability is insufficient. Therefore, battery design should consider operating duration, peak current, depth of discharge, cell temperature, expected ageing, and a practical reserve for demanding mowing conditions [11], [12].

### 3.2. Battery management system

A BMS is essential for monitoring and protecting the battery pack during charging and operation. Its primary functions include cell-voltage monitoring, pack-current measurement, temperature monitoring, state-of-charge (SoC) estimation, state-of-health (SoH) assessment, cell balancing, and protection against abnormal operating conditions. These functions help prevent overcharging, excessive discharge, overcurrent, and operation outside the battery's permitted temperature range. Research on battery management emphasizes that reliable state estimation and protection are central to battery safety, usable capacity, and service life [9], [13], [14].

SoC estimation is particularly important because the mower's remaining operating time depends on the energy available under changing loads. Coulomb counting is relatively straightforward but accumulates measurement errors over time, whereas model-based approaches and Kalman-filter methods can improve estimation when supported by suitable battery models and measurements. SoH estimation provides complementary information about battery ageing and declining capacity or increasing internal resistance. Combining SoC and SoH information can support more realistic runtime prediction and maintenance planning [10], [15], [16].

Thermal management is another important BMS responsibility. Battery temperature can rise during high-current operation, especially when the mower is used continuously in warm outdoor environments. Temperature sensors should be positioned to detect relevant cell or module temperature variations, and the BMS should reduce allowable current or disconnect the pack when safety limits are exceeded. Depending on battery size and operating conditions, passive heat dissipation may be sufficient, but the final design should be supported by thermal measurements rather than assumptions [17], [18].

## 4. INTELLIGENT MOTOR CONTROL

### 4.1. Field-oriented control

Field-oriented control provides independent regulation of motor flux and torque-producing current components, enabling precise speed and torque control. In a PMSM drive, FOC commonly uses measured phase currents and rotor-position information, together with coordinate transformations and current regulators, to generate inverter switching commands. Its principal advantages include smooth torque production, good dynamic response, and effective operation under changing loads. These characteristics make FOC a strong candidate for a mower blade drive where maintaining rotational speed can improve cutting consistency [19], [20].

However, FOC requires accurate motor parameters, appropriate current sensing, and sufficient processing capability. Parameter variations caused by temperature and motor ageing can affect control accuracy, while rotor-position sensing may increase cost and wiring complexity. Sensorless techniques can reduce hardware requirements, but their performance must be evaluated at low speed and during rapid load changes. For a practical mower conversion, the additional complexity of FOC is justified when accurate speed regulation and improved load response are important design objectives [20], [21].

### 4.2. Direct torque control

Direct torque control regulates electromagnetic torque and stator flux through the selection of inverter voltage vectors. Unlike conventional FOC, classical DTC does not rely on the same cascaded current-control structure and can provide a rapid torque response. This characteristic is potentially beneficial when the blade encounters sudden increases in cutting resistance. Nevertheless, conventional DTC may produce higher torque and flux ripple and variable switching frequency, which can increase acoustic noise and electrical stress [22], [23].

Improved DTC methods seek to reduce these disadvantages through space-vector modulation, predictive techniques, and additional control loops. Comparative studies of induction motor and PMSM drives show that the relative performance of FOC and DTC depends on motor type, controller structure, switching strategy, and operating conditions [22]–[24]. For lawn mower applications, FOC may be preferable when smooth blade-speed regulation is the main objective, whereas an enhanced DTC implementation may

be attractive where rapid torque response is prioritized. A final selection should be based on measured cutting performance, current ripple, efficiency, temperature, and controller cost.

### 4.3. Adaptive speed control according to grass conditions

A fixed blade-speed command does not necessarily provide the best performance under all grass conditions. Dense, wet, or tall grass can increase cutting resistance, while short and sparse grass generally requires less mechanical effort. A controller that monitors motor current, speed deviation, or estimated torque can use these variables as indirect indicators of cutting load. It can then adjust the motor command to maintain adequate blade speed without continuously operating at unnecessarily high power.

An adaptive strategy can be implemented through a supervisory controller that modifies the speed reference according to estimated load. For example, a moderate increase in current accompanied by a reduction in blade speed can trigger a controlled increase in torque-producing current, provided that battery and motor limits are not exceeded. If the load remains excessive, the controller can reduce forward travel speed, limit blade demand, or initiate a protective shutdown. This approach connects the motor controller with the BMS and operator interface, creating a coordinated response rather than treating each subsystem independently.

Grass height and density should not be treated as identical variables. Height may be measured or selected through a cutting-height setting, whereas density and moisture can vary considerably across a mowing area. A future intelligent mower could combine motor-current measurements with blade-speed feedback, travel speed, and environmental or optical sensing to estimate cutting demand. However, direct experimental calibration is required because motor current is also affected by acceleration, blade geometry, friction, and transmission losses.

## 5. MOTOR OVERLOAD AND OVERHEATING PROTECTION

Motor protection is necessary because prolonged high torque, blocked blades, poor ventilation, and repeated acceleration can increase winding and power-electronic temperatures. A practical protection system should monitor phase current, DC-link current, motor temperature, inverter temperature, and blade speed where sensors are available. Current-based overload detection can identify abnormal loading, while thermal sensors provide a more direct indication of accumulated heating. Combining electrical and thermal measurements is more reliable than depending on a single threshold [8], [25].

Protection should operate in several stages rather than relying only on immediate shutdown. Under moderate overload, the controller can temporarily limit torque or reduce the blade-speed reference to prevent excessive current. If the temperature continues to rise, the system can progressively reduce available power and alert the operator. Severe overcurrent, a stalled blade, or a temperature exceeding the permitted limit should trigger disconnection through a suitable protective mechanism.

Mechanical obstruction deserves particular attention because grass, branches, stones, or other debris can abruptly stop the blade. The controller should detect an abnormal combination of high current and low rotational speed and respond quickly enough to prevent motor or inverter damage. The system should also prevent automatic blade restart after a protective shutdown until the operator has safely inspected the machine. These measures should be integrated with blade guards, emergency stops, and operator-presence interlocks.

## 6. INTEGRATED DESIGN ASSESSMENT AND RESEARCH GAPS

The major engineering challenge is the coordination of mechanical, electrical, and control subsystems under highly variable cutting conditions. Table 1 summarizes the principal design options and their implications for a converted lawn mower. The comparison indicates that no single motor, battery, or control strategy is universally optimal because the final configuration depends on mower size, cutting width, operating duration, terrain, and expected grass conditions. Consequently, component selection should follow a system-level assessment supported by measurements.

The evidence also reveals several research gaps that limit direct comparison between electric mower designs. First, published studies do not yet provide a widely adopted test protocol for measuring energy consumption, cutting quality, runtime, and motor temperature under controlled grass conditions. Second, the interaction between blade geometry, cutting height, grass moisture, and electrical load requires further experimental investigation. Third, few studies integrate BMS data, motor-control feedback, and mechanical load estimation into a single validated control architecture. These gaps prevent reliable generalization of performance results across different mower sizes and operating environments.

Future research should prioritize instrumented prototype testing under repeatable conditions. Tests should vary grass species, height, density, moisture, cutting width, and travel speed while recording battery current, voltage, SoC, blade speed, motor temperature, and mowing quality. Hardware-in-the-loop testing can support controller development before field deployment, while long-duration trials can evaluate battery ageing, mechanical durability, and protection reliability. Comparative evaluation of FOC and DTC should use the same motor, inverter, battery, and cutting conditions to avoid attributing differences to unrelated hardware variations [26], [27].

Table 1. Design considerations for electrifying conventional lawn mowers

| Subsystem | Potential design option | Main advantage | Key engineering concern |
|---|---|---|---|
| Powertrain | Single-motor or dual-motor | Flexible mechanical arrangement | Independent blade and wheel control |
| Motor | BLDC, PMSM, or induction motor | Efficient electric drive | Torque, speed, cost, and cooling |
| Transmission | Direct drive, belt, or gears | Adaptation of motor speed to blade speed | Alignment, vibration, and mechanical losses |
| Battery | Lithium-ion or LFP | Rechargeable energy storage | Capacity, peak current, mass, and safety |
| BMS | Voltage, current, and temperature monitoring | Battery protection and state estimation | Sensor reliability and thermal limits |
| Motor control | FOC or DTC | Controlled speed and torque | Complexity, ripple, and response |
| Adaptive control | Current- and speed-based load estimation | Response to changing grass resistance | Calibration and false load detection |
| Protection | Current limiting and thermal shutdown | Reduced risk of component damage | Correct thresholds and safe restart logic |

## 7. CONCLUSION

The electrification of conventional lawn mowers requires coordinated mechanical conversion and electrical system integration. A suitable architecture combines an appropriately rated electric motor, inverter, battery pack, BMS, and protective control functions, with a separate propulsion motor where independent wheel control is required. Battery monitoring and thermal management are essential for maintaining safe operation, while FOC and DTC provide alternative methods for regulating motor torque and speed. Adaptive control based on current, speed, and estimated cutting load offers a promising way to maintain blade performance as grass conditions change. The review identifies system integration and application-specific validation as the main priorities for further development. In particular, motor protection should respond to both electrical overload and thermal accumulation, while battery protection should remain coordinated with the motor controller. Future prototypes should be evaluated using standardized measurements of energy consumption, cutting quality, operating time, and component temperature across different grass conditions. Such work can establish a stronger engineering basis for reliable, efficient, and practical conversion of gasoline-powered lawn mowers into battery-electric machines.

## REFERENCES

[1] W. Cai, X. Wu, M. Zhou, Y. Liang, and Y. Wang, "Review and development of electric motor systems and electric powertrains for new energy vehicles," *Automotive Innovation*, vol. 4, no. 1, pp. 3–22, 2021, doi: 10.1007/s42154-021-00139-z.

[2] E. Louback, A. Biswas, F. Machado, and A. Emadi, "A review of the design process of energy management systems for dual-motor battery electric vehicles," *Renewable and Sustainable Energy Reviews*, vol. 193, p. 114293, 2024, doi: 10.1016/j.rser.2024.114293.

[3] V. M. Macharia, V. K. Garg, and D. Kumar, "A review of electric vehicle technology: Architectures, battery technology and its management system, relevant standards, application of artificial intelligence, cyber security, and interoperability challenges," *IET Electrical Systems in Transportation*, vol. 13, no. 2, p. e12083, 2023, doi: 10.1049/els2.12083.

[4] S. Nyamathulla and C. Dhanamjayulu, "A review of battery energy storage systems and advanced battery management system for different applications: Challenges and recommendations," *Journal of Energy Storage*, vol. 86, p. 111179, 2024, doi: 10.1016/j.est.2024.111179.

[5] S. Thangavel, D. Mohanraj, T. Girijaprasanna, S. Raju, C. Dhanamjayulu, and S. M. Muyeen, "A comprehensive review on electric vehicle: battery management system, charging station, traction motors," *IEEE Access*, vol. 11, pp. 20994–21019, 2023, doi: 10.1109/ACCESS.2023.3250221.

[6] A. P. O. and K. O. O., "Development of a solar-powered robotic lawn mower," *Journal of Engineering Research and Reports*, vol. 26, no. 7, pp. 310–316, 2024, doi: 10.9734/jerr/2024/v26i71211.

[7] C.-C. Tu *et al.*, "Industry perspective on power electronics for electric vehicles," *Nature Reviews Electrical Engineering*, vol. 1, no. 7, pp. 435–452, 2024, doi: 10.1038/s44287-024-00055-4.

[8] E. Robles, A. Matallana, I. Aretxabaleta, J. Andreu, M. Fernández, and J. L. Martín, "The role of power device technology in the electric vehicle powertrain," *International Journal of Energy Research*, vol. 46, no. 15, pp. 22222–22265, 2022, doi: 10.1002/er.8581.

[9] H. M. Hussein, A. Aghmadi, M. S. Abdelrahman, S. M. S. H. Rafin, and O. Mohammed, "A review of battery state of charge estimation and management systems: Models and future prospective," *Wiley Interdisciplinary Reviews: Energy and Environment*, vol. 13, no. 1, 2024, doi: 10.1002/wene.507.
[10] F. S. Hwang *et al.*, "Review of battery thermal management systems in electric vehicles," *Renewable and Sustainable Energy Reviews*, vol. 192, 2024, doi: 10.1016/j.rser.2023.114171.
[11] Y. Ortiz, P. Arévalo, D. Peña, and F. Jurado, "Recent advances in thermal management strategies for lithium-ion batteries: a comprehensive review," *Batteries*, vol. 10, no. 3, p. 83, 2024, doi: 10.3390/batteries10030083.
[12] N. Ghaeminezhad, Z. Wang, and Q. Ouyang, "A Review on lithium-ion battery thermal management system techniques: A control-oriented analysis," *Applied Thermal Engineering*, vol. 219, p. 119497, 2023, doi: 10.1016/j.applthermaleng.2022.119497.
[13] J. Lin, X. Liu, S. Li, C. Zhang, and S. Yang, "A review on recent progress, challenges and perspective of battery thermal management system," *International Journal of Heat and Mass Transfer*, vol. 167, p. 120834, 2021, doi: 10.1016/j.ijheatmasstransfer.2020.120834.
[14] M. F. Ge, Y. Liu, X. Jiang, and J. Liu, "A review on state of health estimations and remaining useful life prognostics of lithium-ion batteries," *Measurement: Journal of the International Measurement Confederation*, vol. 174, p. 109057, 2021, doi: 10.1016/j.measurement.2021.109057.
[15] L. Su, Y. Xu, and Z. Dong, "State-of-health estimation of lithium-ion batteries: A comprehensive literature review from cell to pack levels," *Energy Conversion and Economics*, vol. 5, no. 4, pp. 224–242, 2024, doi: 10.1049/enc2.12125.
[16] B. Yang *et al.*, "Critical summary and perspectives on state-of-health of lithium-ion battery," *Renewable and Sustainable Energy Reviews*, vol. 190, p. 114077, 2024, doi: 10.1016/j.rser.2023.114077.
[17] J. Kong *et al.*, "Review on lithium-ion battery PHM from the perspective of key PHM steps," *Chinese Journal of Mechanical Engineering (English Edition)*, vol. 37, no. 1, p. 71, 2024, doi: 10.1186/s10033-024-01055-z.
[18] X. Lei, F. Xie, J. Wang, and C. Zhang, "A review of lithium-ion battery state of health and remaining useful life estimation methods based on bibliometric analysis," *Journal of Traffic and Transportation Engineering (English Edition)*, vol. 11, no. 6, pp. 1420–1446, 2024, doi: 10.1016/j.jtte.2024.09.004.
[19] M. Aktas, K. Awaili, M. Ehsani, and A. Arisoy, "Direct torque control versus indirect field-oriented control of induction motors for electric vehicle applications," *Engineering Science and Technology, an International Journal*, vol. 23, no. 5, pp. 1134–1143, 2020, doi: 10.1016/j.jestch.2020.04.002.
[20] C. Attaianese, M. Di Monaco, and G. Tomasso, "Maximum torque per watt (MTPW) field-oriented control of induction motor," *Electrical Engineering*, vol. 103, no. 6, pp. 2611–2623, 2021, doi: 10.1007/s00202-021-01238-0.
[21] M. Furmanik, L. Gorel, D. Konvičný, and P. Rafajdus, "Comparative study and overview of field-oriented control techniques for six-phase pmsms," *Applied Sciences (Switzerland)*, vol. 11, no. 17, p. 7841, 2021, doi: 10.3390/app11177841.
[22] S. Ahmad and H. T. Le, "Effectiveness of field oriented control and direct torque control methods for induction motor speed regulation," *Wseas Transactions on Systems and Control*, vol. 18, pp. 513–526, 2023, doi: 10.37394/23203.2023.18.54.
[23] R. E. K. Meesala, R. R. Udumula, T. K. Nizami, and A. Hosseinpour, "Development of enhanced direct torque control for surface-mounted permanent magnet synchronous motor drive operation," *IET Power Electronics*, vol. 16, no. 11, pp. 1814–1827, 2023, doi: 10.1049/pel2.12504.
[24] T. L. Le and M. F. Hsieh, "An enhanced direct torque control strategy with composite controller for permanent magnet synchronous motor," *Asian Journal of Control*, vol. 26, no. 4, pp. 1683–1702, 2024, doi: 10.1002/asjc.3306.
[25] R. Jing, G. Wang, G. Zhang, and D. Xu, "Review of field weakening control strategies of permanent magnet synchronous motors," *CES Transactions on Electrical Machines and Systems*, vol. 8, no. 3, pp. 319–331, 2024, doi: 10.30941/CESTEMS.2024.00043.
[26] M. G. Simon and D. Fodor, "Comparative analysis of field oriented control and direct torque control through simulation in MATLAB simulink for an automotive drive motor †," *Engineering Proceedings*, vol. 79, no. 1, p. 33, 2024, doi: 10.3390/engproc2024079033.
[27] S. Divya and D. K. Kumar, "Model predictive control-based field-oriented control for speed regulation of electric vehicle PMSM drives," *SSRG International Journal of Electrical and Electronics Engineering*, vol. 11, no. 11, pp. 399–408, 2024, doi: 10.14445/23488379/IJEEE-V11I11P137.

## BIOGRAPHIES OF AUTHORS



**Sajad Abdollahzadeh Anbaran** is affiliated with the Power Electronics and Drives Research Group, Universiti Teknologi Malaysia, Johor Bahru, Malaysia. He can be contacted at email: sajjad.abdollah@gmail.com.