Electric Motor Optimization Based On Artificial Intelligence

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Abstract. High-performance electric motor systems are at the heart of renewable energy infrastructure and transportation. As their applications expand across electric vehicles (EVs), wind turbines, and rail networks, the demands on motor performance now encompass multiple engineering disciplines, including thermal dynamics, structural integrity, and power electronics. This multidisciplinary complexity challenges traditional optimization methods like finite element analysis, which, while accurate, are often too computationally intensive for practical, large-scale, or real-time applications. Artificial intelligence (AI) is rapidly transforming the field by offering powerful alternatives that streamline motor geometry, improve thermal management, and fine-tune control systems for peak efficiency. Techniques such as neural networks, genetic algorithms, and reinforcement learning enable real-time thermal prediction, faster convergence in complex design problems, and adaptive control strategies that respond to battery degradation and driving conditions. Integrating AI with hybrid modeling, digital twin platforms, and rigorous multi-physics validation protocols ensures both speed and accuracy, while leveraging real-time sensor data for continuous optimization. These advances are not merely incremental; they represent a paradigm shift in motor design, enabling simultaneous improvements in energy density, noise reduction, and thermal stability.

Keywords: Artificial Intelligence; Electric Motor; Linear Regression; Neural Network.

1. Introduction

Against the backdrop of the global energy crisis and increasing environmental pollution, new energy vehicles are becoming more and more popular, and are gradually becoming a key path to achieving sustainable development of transportation energy. With the gradual pollution of carbon dioxide to the environment, promoting the popularization of new energy electric vehicles has become a main scientific research area in many countries. Among the many components of new energy vehicles, the electric drive system, as the "heart" of the car, directly determines the driving experience and feedback of the vehicle. In contrast, the suspension comfort of the vehicle is certainly important, but this is not our research center. As an important part of the oil car era, the suspension has gone through a hundred years of precipitation, practice, and renewal, which certainly has a certain impact on our future research because of the lack of foresight. Improving electric motor efficiency even by a few percentage points can lead to substantial energy savings globally, given that motors consume nearly half of all electricity generated. [4] Therefore, in-depth research on the electric drive system, especially its performance optimization, has greater research space and value.

Modern high-performance electric motor systems are at the heart of renewable energy infrastructure and transportation, consuming a significant amount of global electricity according to the International Energy Agency. [1] However, in recent years, the electric drive system has faced some severe challenges. Continuing to rely on the experience of engineers and trivial overlapping replacements can no longer make new progress in a short time. Solving the endurance, power and weight ratio of the electric drive system is imminent. Combined with the background of the times, with the rapid development of artificial intelligence at present, it seems to be a better choice to summarize data based on the big model of artificial intelligence and provide problem points. Artificial intelligence's powerful data processing and decision-making optimization capabilities will greatly improve design efficiency and intelligence, while also achieving collaborative optimization of multiple objectives such as performance, cost, and reliability.

Designing electric vehicles (EVs) involves creating a transportation system powered primarily by electricity rather than fossil fuels, with the goal of improving energy efficiency, reducing emissions, and promoting environmental sustainability. It requires an integrated approach that combines electrical, mechanical, and software engineering to optimize key components such as the electric motor, battery pack, power electronics, and control systems. Beyond technical performance, EV design also considers factors like weight reduction, aerodynamics, safety, user experience, and cost-effectiveness. Ultimately, designing EVs is about innovating mobility solutions that align with the global shift toward cleaner, smarter, and more sustainable transportation. Electric vehicle design is not just about replacing an engine with a motor—it is a rethinking of the entire vehicle architecture to align with sustainability, digitalization, and new mobility paradigms. [5] Focusing specifically on the electric motor—rather than the entire drivetrain system—matters because the motor is the core energy conversion component in an electric vehicle. The electric motor is the single most critical component in determining an EV's performance, efficiency, and driving range. [6] It directly transforms electrical energy into mechanical energy to drive the wheels, and its design has a major impact on the vehicle's performance, efficiency, size, cost, and thermal management. While the drivetrain system includes multiple components, many EVs use simplified or integrated drivetrains with far fewer moving parts than internal combustion vehicles, making the motor's role even more dominant. Optimizing the electric motor can lead to significant gains in torque density, range, cooling efficiency, and energy savings, and directly influences the requirements for other drivetrain elements. Moreover, the latest technologies like a direct-drive system allow some electric vehicles (EVs) not to have other parts of the drivetrain at all, which also proves the centrality of a motor.

The transformation of the global energy sector to a sustainable industry and the aim to be carbon neutral in the upcoming years have led to the introduction of electric vehicles (EVs) as the key element of transport in the future. At the core of this revolution is an electric motor and its design radically determines the performance, efficiency, and driving range of vehicles. While traditional motor design techniques have served well, the increasing demand for higher efficiency, lower cost, and lighter weight in next-generation EVs poses complex challenges that conventional methods struggle to address. Adding artificial intelligence into the production of electric motors is much more than innovation; it is a paradigm shift to intelligent, adaptive and future-proof systems[7]. Artificial intelligence (AI) is, hence, gradually being used as an effective tool to optimize the design of motors. By applying machine learning, deep neural networks and advanced multivariable optimization methodologies, engineers can streamline the search of vast design spaces, make corrective predictions of performance and conduct intelligent optimization over the design spaces. The paradigm is more than a quantum jump in engineering practice; it is also the beginning of a new era of smart, high-performance, and sustainable electric mobility.

2. Basic Principles Behind Electric Motors

A cogent understanding of the basic working principles of electric motors, which is based on electromagnetic theory, is necessary of the process of establishing the practical ways out of the current challenges that touch on the devices. Based on this, the article outlines the blatant shortcomings that all the electric motors are facing now and how their forthcoming technology, such artificial intelligence, can help counter these problems.

2.1 Principal Theories Behind Electromagnetism

Electric motors operate based on electromagnetic principles. They are based on an interaction of magnetic fields and electric current. To understand this interaction, it is necessary to think about the Law of Electromagnetic Induction, which was suggested by Faraday, and suggests that an electromotive force could flow up in a conductor under the action of a change of magnetic flux. This law describes the way to use the flow of the matter in the magnetic field to get the current. The Lorentz Force Law describes the force that a current-carrying conductor experiences in a magnetic field; it is this force that makes the motor system move. Ampere's Circuital Law connects magnetic fields and the electric currents which generate them, explaining the way in which motor windings can generate rotating magnetic fields. These principles combined present the main physical basis by which the motor runs and they help engineers come up with systems that can effectively convert electrical energy into mechanical energy in devices they build.

2.2 Fundamental Operating Principles of Electric Motors

The fundamental principle of a motor is that when an electric current flows through a conductor placed in a magnetic field, it experiences a mechanical force. In practice, motors use coils of wire mounted on a rotor or stator. When current passes through these windings, magnetic fields are generated, interacting with permanent magnets or other electromagnets to produce rotational motion. The continuous rotation is achieved through mechanisms such as commutators in DC motors or by creating rotating magnetic fields in AC motors. These mechanisms ensure that the force on the rotor is maintained in the same rotational direction. Understanding the fundamental working principles of electric motors highlights both their strengths and their limitations

Traditionally, the Lorentz force is used to drive electric motors: by passing current through a conductor inside a magnetic field, a force is generated which causes the motion. The concept behind the underlying physical principle is simple, but realizing this into systems that are efficient, scalable, and robust by being capable of producing motor systems is a monumental engineering task. Although considerable progress has been made in the field of motor design over the recent decades, there are still a few basic weaknesses. Efficiency losses that often accompany the high-load operation become even more acute at higher temperatures and thus affect the performance and the durability. In addition, a vast amount of high-performance motors depend on rare-earth materials in their magnets, publicizing supply-chain risks and increasing costs. Also, requiring fine control of torque, velocity, and thermal response over a wide range of real-world conditions, there is another level of complication, which requires complex power-electronics hardware and elaborate control algorithms.

2.3 Flaws of Electric Motors

Despite the widespread adoption of electric motors, and the maturity of corresponding technologies, they are limited by several limitations. Energy efficiency in extreme conditions remains one of the foremost concerns and this is a factor that manufacturers have highly put into consideration. Life span is equally an issue, where it is not so rare that an electric motor lasts only five years, a number that is dramatically less than that of an internal combustion engine, which lasts roughly ten years. Moreover, control dynamics, the energy efficiency as well as performance depend directly on the relationship between weight and power and any limitation of such a relationship increases the problem. With automobile companies adopting the notion of building lighter and more compact vehicles that still need to perform, motor systems will have to be developed to meet the more rigorous requirements. Such technological limitations show the dire need for innovation and optimization to be done in electric motor technologies, especially as the automotive industry transitioning to full-on electrification. This is because the fact that motors used under a high-power regime result in high levels of heat, which can potentially cause a level of material degradation, and negatively impact the efficiency. Economic feasibility is another challenge worth worrying about, considering that the construction of permanent magnets requires expensive and non-renewable materials like neodymium and dysprosium. It is also difficult to ensure durability and reliability throughout the miles of an EV, which are usually more than hundreds of kilometers. This is a concern regarding scalability as the designs of the motors have to be able to adjust and fit an array of vehicles including compact city cars to even heavy-duty trucks and buses.

2.4 Role of Artificial Intelligence in Overcoming Challenges

The impact of the artificial-intelligence-powered motors in electric cars is tremendous and complex. Through topology optimization, such motors may extend range per charge, compress development schedules, and limit reliance on rare-earth material by hundreds of percent. [2]As electric motors have become more and more enwoven in recent industry, infrastructure, and consumer products, there is an even higher premium on systems being intelligent, and resilient at the same time. One of the most promising solutions to stimulate the traditional motors lies in the implementation of Artificial Intelligence (AI). Lastly, AI is imbuing a certain adaptability, which cannot be traced by previous control algorithms, as well as by manual supervision, and providing a learning capacity that disrupts both motor operation and maintenance.

The opportunity to examine large quantities of real-time data and diagnose early signs of wear or malfunction, long before it turns into a full-scale failure, is the potential of AI that can transform predictive maintenance. This predictive feature helps overcome unpredictable offline occurrences, as well as reduce operational expenses on repairs and replacements. In addition, AI promises to be able to optimize motor energy consumption in a dynamically variable manner by attaining new parameters of operation in the face of different loads, environmental conditions, and use patterns, which traditional control systems usually fail to achieve. Besides, of equal importance, AI enables fault diagnostics and sophisticated fault detection. Trends in vibration, temperature, and current measurements can be analyzed to identify anomalies by the AI models that would not be possible to observe in normal conditions through the conventional monitoring procedures [8]. Therefore, artificial intelligence allows predictive maintenance in real-time, greatly reduces electric motor outages, and protects reliable, secure operation in areas of important concerns, including transportation, manufacturing, and energy.

2.5 How AI can be used for problem solving

Artificial intelligence (AI) is not a longer hypothetical anymore, it is already used in electric motor systems and provides tangible results contributing to solving some of the most demanding tasks involving operation and management of motors. At the core of this revolution is the ability of AI to extract knowledge, to make decisions and to optimize performance through a loop. Practically, one can use the machine-learning models, namely, neural networks, to be trained with both the past and the present sensor data to find the patterns that can represent some failure or ineffective performance. An example of model so trained is that it can identify subtle vibrations or current aberrations which precede motor failure and allows engineers to take action before any real harm is caused. Furthermore, the neural networks and the genetic algorithms have proved to be better than the classical parameter optimization of the induction motors.[9]Such predictive ability constitutes a substantial improvement over the traditional time-based maintenance strategies that can either miss the onset of a defect or lead to unjustified servicing activity.The other significant usage of AI is the use of digital twins- a virtual duplicate of the real motors that behaves similarly when subjected to varying conditions so that the engineers can confirm modifications and predict malfunctions without interfering with the real motors. Digital twins therefore act as diagnostic tools, innovations and optimization platforms. AI can also be incorporated directly into motor controllers due to the emergence of edge computing. This decentralizes decision-making, allowing for real-time responsiveness without the delays associated with cloud-based systems. As a result, AI becomes an integral part of the motor system itself, enabling faster, more intelligent responses to changing demands and operational conditions.

3. Why Use Artificial Intelligence To Optimize The Design of Electric Motors

Artificial Intelligence offers significant advantages that traditional design methods struggle to match. Not only can artificial intelligence be much more efficient but it also provides a faster way to eliminate configuration errors. With AI, you can create fast digital twins that replace time-consuming finite element analysis simulations. Electric vehicles can lose up to 10% of their driving range due to inefficient motor control—an area AI can dramatically improve. [10]

3.1 How does Artificial Intelligence Work?

Artificial Intelligence works by enabling machines to simulate human-like intelligence through data processing, learning, and decision-making. At its core, AI uses algorithms to analyze large volumes of data, identify patterns, and make predictions or decisions based on that information. This process often involves machine learning, where the system is trained using example data to improve its accuracy over time without being explicitly programmed for every task. In more advanced forms, such as deep learning, AI models use neural networks inspired by the human brain to recognize complex patterns in images, text, or speech. AI algorithms can simulate over 100 million design iterations in hours, compared to weeks using traditional finite element methods. [11] Once trained, the AI system can process new inputs, adapt to changing conditions, and continuously refine its performance, making it a powerful tool for solving complex, real-world problems. Behind the scenes, AI involves various mathematical equations and concepts like linear algebra, probability & statistics, and so on. It uses equations from Linear Algebra to demonstrate the function of neural networks.

3.2 Necessity of Using Artificial Intelligence

Artificial Intelligence (AI) has become increasingly essential in the design of electric motors due to its ability to optimize complex systems far beyond human capabilities or traditional methods. When man engineers make a motor design, they are bound to focus their attention on the most easily measurable parameters, that is, torque, efficiency, and cost. In comparison, AI uniquely can question and optimize a very large and interconnected number of variables including the distribution of magnetic flux, winding designs, cooling effectiveness, and stress margins on materials. These parameters often require long periods to be optimized manually or just disregarded due to time or manpower constraints. With the usage of machine learning and evolutionary algorithms, engineers can actively look over a huge area of design combinations that would prove to be impractical to test empirically. Trained AI systems equipped with predictive models make predictions about metrics of system performance, thus, eliminating the necessity of extensive simulations. Such functionality makes design go much faster and also opens up configurations that human designers would not otherwise consider. Furthermore, AI has made it easier to solve both multi-objective optimization problems through which competing requirements (like the weight of the parts and power optimization) can be balanced fairly well with a high level of efficiency. That memory capacity is a game-changer in industries where space, weight and performance are critical, such as electric vehicles, robotics, and aerospace. The technology also helps to check wastage in prototyping by selecting the most likely successful candidates before fabrication. Moreover, the fact that it constantly adapts to new data also makes sure that with every iteration, it makes it slightly better and more effective than the previous one, and in the end, develops incrementally smarter and more efficient motor architectures. Given the growing necessity of high-performance lightweight, energy-efficient, and cost-effective electric motors, AI has developed to the status of an essential tool, rather than a beneficial addition. It transforms the old, linear, trial-and-error design process into a smart, data-driven process that makes them more creative and accurate. As a result, AI is not only a secondary process but also a driver of the new generation of electric motor engineering.

3.3 Artificial Intelligence's Linear Regression Function for Optimizing Electric Motor Design

When utilized in the form of linear regression, Artificial Intelligence is essential in optimizing the design of the electric motor by being able to make objective and rule-based connections between the design variables and the performance of a specific system by means of clear, data-driven correlations. Linear regression is one of the core machine learning methods that estimate the effect of input factors e.g. coil winding size, type of magnetic materials, or geometry of rotor, on output data e.g. efficiency of the motor or torque. Electric motor engineers are often required to predict the effects of small changes in a part on their overall performance, which may not always be solved intuitively or through the trial-and-error method. A linear regression model based on AI will be able to extract trends and patterns in large amounts of data, acquired through previous motor design, simulation or experimental data. Internalization of these relationships, the model can predict the outcomes of manipulating design variables, thus allowing quicker informed decisions. An example could be linear regression model, which suggests that the more the density of the core material, the more the efficiency up to a particular limit beyond which there will be a diminishing effect. These insights can be precious when it comes to making accurate evidence-based design amendments without having to waste their time on ineffective change. Moreover, since linear regression provides a simpler computational requirement compared to other methods of artificial intelligence, the technique can be used in the early stage of the design to reduce candidate selection before using more detailed models or nonlinear optimization. It can also give data that can be compared to more complicated models in a kind of baseline and have easily interpretable results that the engineers can rely on and construct to an even greater degree. Finally, the linear regression feature of AI simplifies the process of electric motor development, as the application indicates what can be done with the help of data, reduces the design process and accelerates the process, and encourages cost-effective optimization. It allows engineers to build quality, evidence-based modifications to improve motor performance, efficiency, and durability, hence proving itself as a fundamental tool in the intelligent design of electric motors of the future.

3.4 Summary

AI could advance the design of the electric motor because it can efficiently optimize complex variables in a decent timeframe and with a high degree of accuracy, making it perform better than standard techniques. Instead of using long-term simulations, it replaces them with quick digital models that supplement data-based, predictive algorithms that can predict performance and identify faults in design. Linear regressions help engineers make definite early decisions but in a precise manner since they determine with an immediacy of how changes in the components of the motor affect the operation. AI is therefore transforming the design of electric motors into a complex, economical, and ever-sleek science and field, ultimately developing the innovation and reducing the time and cost of the development.

4. How to Use AI to Optimize Electric Motor Design

AI can significantly improve electric-motor design, through the optimization process. Using this feature of the AI, performing linear regressions, engineers may determine the performance of the motor highly accurately, given design specifications, including geometry, materials and winding patterns. These surrogate models enable rapid evaluation of design alternatives without the need for time-consuming simulations. AI helps manufacturers move from reactive to proactive motor diagnostics and performance tuning. [12] Optimization algorithms like neural systems then explore the design space to find the best-performing configurations. Validated through high-fidelity simulations or testing, AI-generated designs reduce development time, lower costs, and improve overall motor efficiency and performance.

4.1 Key Ideology of How AI Optimizes Design

Linear regression can support electric motor design optimization by providing a simple, fast, and interpretable way to estimate how design parameters affect performance metrics such as torque, efficiency, or losses. Linear regression, when combined with AI, offers a scalable approach to predict motor performance in large datasets [13]. Training on simulation or experimental data allows quick predictions and enables sensitivity analysis by highlighting which variables most influence performance. The current approach allows the engineers to establish important design parameters and examine takeoffs, especially between efficiency and weight. In spite of the fact that the model relies upon linear associations, hence, has limited accuracy in supporting multidimensional, nonlinear effects, it still offers a sound initial foundation model or low-end framework before more sophisticated artificial intelligence methods like neural networks are implemented. In comparison, neural networks and especially deep learning models are a substantial tool that can draw complex and nonlinear relationships between a large set of design variables and resulting performance measurements. As an example, these networks can calculate hundreds of variables simultaneously, provide performance predictions within milliseconds, and can be used in conjunction with genetic algorithms or learning by reinforcement systems to improve designs on a constant feedback basis. In addition, the core of optimisation, which is based on the principles of Multivariable Calculus, applies the tool of gradient descent, Newton-Raphson approaches or multipliers to the language to the solution of constrained optimisation scenarios. The usage is especially beneficial as the objective and constraint conditions can be represented analytically or in the form of differentiable models.

4.2 How Do These Ideologies Work

Linear regression assumes linear correlation of variables under investigation, be it the latter ones related to design parameters (i.e., rotor diameter, winding turns, and any output-related phenomena, e.g., torque or efficiency). The least-squares is used to estimate the best regression line that describes the data by attempting to reduce the space between the observed values and the values predicted using the line. In this regard, a researcher can use linear regression to quickly get results in terms of how an increment in winding turns will affect the generation of torques. When the relationship is close to linear then the resulting model can support the early design judgment. Secondly, neural networks are inspired by the human brain and consist of layers of interconnected neurons that adjust weights during training. When fed a large dateset of input parameters and corresponding performance results, the network learns the patterns and generalizes them. Finally, multi-variable based optimization is based on derivatives to determine the direction in which to change design parameters to improve a performance objective. Techniques like gradient descent iteratively adjust multiple variables until the best design is found within given constraints.

4.3 Current Exploration

Across the globe, researchers and companies are increasingly leveraging artificial intelligence (AI) to revolutionize electric motor design, making it faster, smarter, and more efficient. In the UK, Monumo is using advanced AI simulations—running up to 10 million scenarios a day—to explore optimal motor configurations that reduce material use, noise, and reliance on rare earth elements. In Japan, Mitsubishi Electric and TMEIC have co-developed an AI-based motor design support system that learns from historical data to automatically generate and evaluate multiple motor specifications, significantly reducing the design cycle. In the U.S., Hinetics, a spin-off from the University of Illinois, applies AI-driven optimization techniques to develop high-efficiency electric motors and generators for aerospace and renewable energy, including a 10 MW superconducting motor project funded by ARPA-E. Meanwhile, researchers at UNSW Sydney have created an AI-assisted design program for permanent magnet synchronous motors (IPMSMs), enabling the design of motors that use fewer rare earth materials without compromising performance. In Europe, the CREATOR project—a German Austrian research collaboration--combines AI with traditional optimization techniques to simultaneously refine motor shapes and geometries for better performance and mechanical stability. Ultimately, AI is not just a tool for optimization but a transformative force, redefining the future of electric mobility and sustainable electrification. [3] Together, these efforts highlight how AI is transforming electric motor development, enabling more sustainable, high-performance designs across a range of industries.

5. Conclusion

The development of electric cars is critical to the needs of the world in terms of energy sustainability, the minimization of carbon emissions, as well as preventing environmental degradation. The crux of this change is the electric motor, the performance and efficiency of which play a deterministic role in the uptake of electric vehicles. The conventional design methodologies are becoming limited by the complexity and the demanding needs of the modern motors. The introduction of artificial intelligence into design of motors is also such an evolution. Such instruments as linear regression, neural networks, and optimization algorithms form the data-driven paradigm of facing thermal management, efficiency loss, material cost, and control accuracy. In contrast to traditional methods, artificial intelligence can handle large amounts of data, do real-time learning, and navigate design spaces at increased rates and greater accuracy. Predictive models and digital twins allow engineers to conduct proactive decision-making, reduce dependence on the trial-and-error principle, and accelerate development processes and associated costs. The future of electric cars and trucks does not simply rely on the positive effect they will have on the environment though, it also depends on smart parts. With the motor development industries adopting the application of AI-augmented applications, it is apparent that it has reached a point where it is impossible to proceed without this technology. Artificial intelligence is generating safer, more efficient, more sustainable transportation by reinventing the electric motor design. The inter-departmental collaboration between artificial intelligence and motor engineering can therefore be hailed as a unified pledge towards a greener and wiser world.

References

[1] Waide, P., & Brunner, C. (2011). Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems InternatIonal energy agency Energy Efficiency Series. https://iea.blob.core.windows.net/assets/d69b2a76-feb9-4a74-a921-2490a8fefcdf/EE_for_ElectricSystems.pdf

[2] Dickson, I. (2025). How artificial intelligence can help optimize electric vehicles. HERE. https://www.here.com/learn/blog/how-ai-optimizes-electric-vehicles

[3] Brite. (2023, July 6). Accelerating the Future: The Impact of AI on EV/Mobility and Energy Tech | BRITE Energy Innovators. BRITE Energy Innovators | Empowering Founders to Launch Energy Technology Solutions. https://brite.org/accelerating-the-future-the-impact-of-ai-on-ev-mobility-and-energy-tech/

[4] Sustainability Directory. (2025, March 23). Electric Motor Efficiency → Term. Energy → Sustainability Directory. https://energy.sustainability-directory.com/term/electric-motor-efficiency/

[5] Sustainability Directory. (2025a, March 5). Electrified Vehicle Architecture → Term. Energy → Sustainability Directory. https://energy.sustainability-directory.com/term/electrified-vehicle-architecture/

[6] Arora, N. (2025, March 25). Impact of Motor on Torque and Performance in an Electric Vehicle. –. https://evjoints.com/ev-guide/impact-of-motor-on-torque-and-performance-in-an-electric- vehicle/

[7] Yamini, E., Zarnoush, M., Jalilvand, M., Zolfaghari, S. M., Esmaeilion, F., Taklifi, A., Garcia, D. A., & Soltani, M. (2025). Integration of emerging technologies in Next-generation electric vehicles: Evolution, advancements, and regulatory prospects. Results in Engineering, 25, 104082. https://doi.org/10.1016/j.rineng.2025.104082

[8] Dupont, M. (2024, June 3). Predictive Maintenance Revolutionized by AI Models. Labelvisor; Labelvisor. https://www.labelvisor.com/predictive-maintenance-revolutionized-by-ai-models/

[9] Soares, R. C., Silva, J. C., de Lucena, J. A., Filho, A. C. L., Ramos, J. G. S., & Brito, A. V. (2024). Integration of Bayesian optimization into hyperparameter tuning of the particle swarm optimization algorithm to enhance neural networks in bearing failure classification. Measurement, 115829. https://doi.org/10.1016/j.measurement.2024.115829

[10] Dickson, I. (2025). How artificial intelligence can help optimize electric vehicles. HERE. https://www.here.com/learn/blog/how-ai-optimizes-electric-vehicles

[11] Hitachi Ventures. (2024, December 11). How AI is Shaping the Future of Design, Simulation and Optimization. Medium.
https://medium.com/@HitachiVentures/how-ai-is-shaping-the-future-of-design-simulatio n-and-optimization-6b88819c77cb

[12] Jackley, M. (2024, December 23). Using AI in Predictive Maintenance. Oracle.com; Oracle. https://www.oracle.com/ee/scm/ai-predictive-maintenance/

[13] Kang, J. I., Parekh, H., Ramdas, P., Lee, S., & Woo, J. (2022). Comparing Regression Models Predicting the Price of Used Cars in Big Data. 2022 IEEE International
Conference on Consumer Electronics-Asia (ICCE-Asia).
https://doi.org/10.1109/icce-asia57006.2022.9954633