International Journal of Multidisciplinary Research and Growth Evaluation.

Innovative design approaches for high-efficiency motors in industrial applications

Priyanka Das
Manufacturing Engineer, Cincinnati, USA

* Corresponding Author: **Priyanka Das**

Article Info

ISSN (online): 2582-7138
Volume: 06
Issue: 01
January-February 2025
Received: 15-12-2024
Accepted: 16-01-2025
Page No: 1907-1911

Abstract
High-efficiency motor application in diverse industries faces setbacks, including raising environmental concerns and increasing energy costs to align with innovative needs. Overreliance on traditional motors in industrial applications limits a push for industrial practices to advance modern efficiency standards in promoting an innovative industrial culture. Advocating for effective motors to shape various levels in industrial applications envisions declining resource and environmental concerns, such as adverse implications from global warming. The fundamental innovative models sustain the efficacy and reliability of broad industrial applications. The differentiated motor designs aid in addressing challenges such as energy losses, growing environmental concerns, and expectations for modern industrial performances. Most application trends in broad industrial needs highlight an insight into emerging trends for high-efficiency motors shaping transformative technologies. Practical guidance for engineers utilizing various motors and innovative applications in policymaking. Through the lens of such incorporation, a diversified vision encompasses attributes to achieve an energy-efficient industry.

DOI: https://doi.org/10.54660/.IJMRGE.2025.6.1-1907-1911

Keywords: Motor, high efficiency, innovative, industrial, technology

1. Introduction

High-efficiency motors in industrial applications help organizations cope with increasing energy costs, pursue sustainable practices, and address environmental concerns. It is fundamental to reiterate the reliability of traditional motor designs but affirm their current failure to offer modern efficiency required standards to validate innovative approaches (Suresh *et al*., 2024, p. 3) [2]. As such, engineers are integrating cutting-edge manufacturing techniques correlated with technologies to redefine motor performance for higher efficiency in industrial applications. This paper explores emerging motor applications by exploring designs used to revolutionize the industry. By exploring different innovative motors used in industrial applications, the paper envisions a future that reduces carbon footprints, sustains energy saving, and enhances reduced global warming.

2. Background and Significance

Electronic motors create opportunities for equipment to support processes such as automation and manufacturing. Although traditional motor designs are reliable, they continuously exhibit energy inefficiencies in most industries' consumption requirement levels. The rise in energy costs and global uproar on environmental concerns amass more pressure to invest in efficient technologies and regulatory standards. An innovative design to accommodate high motor efficiencies harnesses an objective to address amassing pressure through leveraging advancements (Alberti & Troncon, 2020, review of standards and regulations, para 1). For instance, highly efficient motors accommodate advancement for materials, control systems, and manufacturing techniques. In most dynamic engineering industries, investments involve optimized rotors, rare-earth magnets, and stator geometrics for performance efficiency (Suresh *et al*., 2024, PV generic existing designs, p.7, para 2) [2]. In addition, the benefits of designing high-efficiency motors in industrial applications such as Information of Things (IoT) enabled sensors and algorithms sustain performance optimization. The fundamental significance of high-efficiency motors prompts the ability to reduce operational costs, extend motor lifespan, lower carbon print, and achieve competitiveness. Environmental stewardship guaranteed through high-efficiency motors ensures the industry achieves substantial energy savings for global efforts to combat climate change (Khattra *et al*., 2024, renewable energy, para 2, p. 210) [8]. This paper explores the importance of developments that provide insights into potential motor transformation for industrial energy practices.

3. Objective of the Paper

The paper aims to elucidate innovative design approaches for the efficiency and performance of electric motors in industrial applications. The paper delves into substantial energy-saving mechanisms as a growing culture for industries to transition from traditional to innovative approaches for performance improvement. The presentation examines changes in manufacturing techniques and technologies processes to achieve efficiency and operational level suitability. Innovative designs aim to support sustainable motor technology advancement in reducing energy consumption, minimizing environmental impact, and meeting the growing demand for high-efficiency solutions in dynamic industrial systems.

Motors Used in Industrial Application

Motors are essential in industrial applications, powering machinery and equipment in diverse sectors. Choosing the appropriate motor type relies on specific operational requirements, including efficiency, load, speed control, and environmental conditions. The three common motor types used in industrial settings are induction, synchronous, and servo motors, highlighting their key features, advantages, and typical applications.

Induction Motors

Induction motors are the cornerstone for industrial application success in varied settings attributed to simplicity, reliability, and cost-effectiveness. Asynchronous or induction motors convert electrical energy to mechanical energy without electrical connections (Chenchevoi *et al*., 2021) [3]. The motors operate on the principle of electromagnetic induction on a rotor energized by the stator's magnetic field through a fundamental induction process.

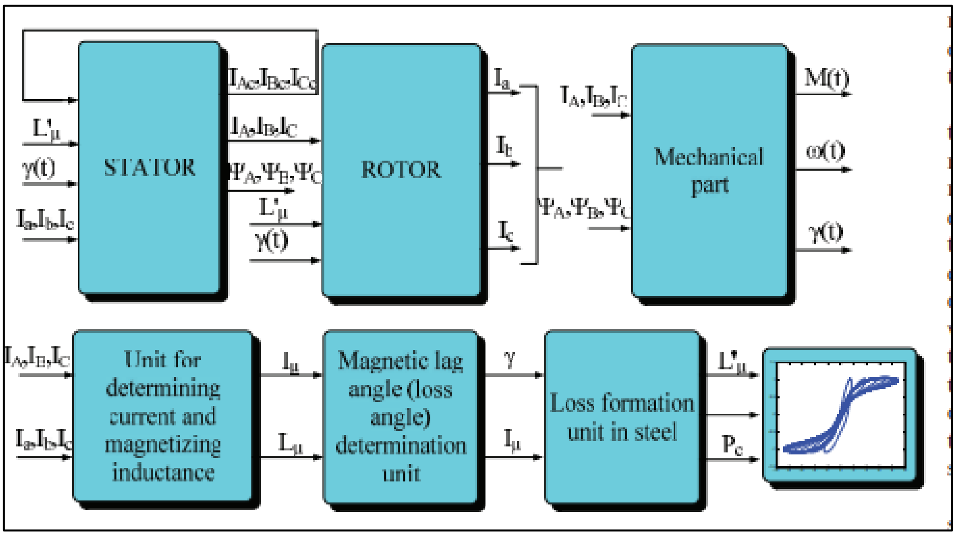

Fig 1: Mathematical model for an induction motor

A representation of mathematical model used in induction motors (Chenchevoi *et al*., 2021) [3]

Mechanical energy generated through induction motors fulfills various features that involve:

- A well-articulated process fosters minimal maintenance requirements.
- A single-phase to sustain small efficiency and a three-phase heavy industrial configuration (Chenchevoi *et al*., 2021, p. 68) [3].
- Foster high efficiency and durability.

Applications

The motors remain relevant in innovative industrial applications thus, utilized in diverse manufacturing areas:

- Pumps, compressors, and conveyors.
- Fans, blowers, and material handling equipment.
- General machinery for constant speed and moderate torque.

Advantages

Motors powered by simplicity in converting the magnetic field to innovative culture for industrial applications offer diverse benefits:

- **Simplicity**: A flexible design with fewer components, reducing maintenance costs.
- **Reliability:** an advanced three-phase model for induction motors for a high power-to-weight ratio.
- **Suitability:** Asynchronous motors encourage designing and manufacturing products in harsh industrial environments (Credo *et al*., 2022, p. 1258) [4].

Limitations

While induction motors offer a promising future in innovative electronic conversions, it also presents challenges.

- **Functionality:** Relying on the magnetic field in high-efficiency motor applications faces limited speed control capabilities without external drives and concerns in a dynamic industrial environment.
- **Unguaranteed Performance:** Sustaining a long-term design relying on simplified motors fosters inefficiency concerns at variable loads due to unguaranteed advanced control systems in the industry.

Synchronous Motors

Synchronous motor is a second fundamental innovative design incorporated into industrial applications to electromagnets to create high-speed operations, advance controllable power factor, and harness sustaining speed performance. The motor also operates at a constant speed regardless of load changes, synchronized with the power supply frequency. A growing demand for the motor fosters its demand for special winding for rotor powers. Therefore, synchronous motor, constant speed, and efficiency in well-defined controlled power determine efficacy for the final product. It remains effective for applications in industrial dynamics approaches requiring precise speed and power factor correction (Ji *et al*., 2021, introduction, para 2).

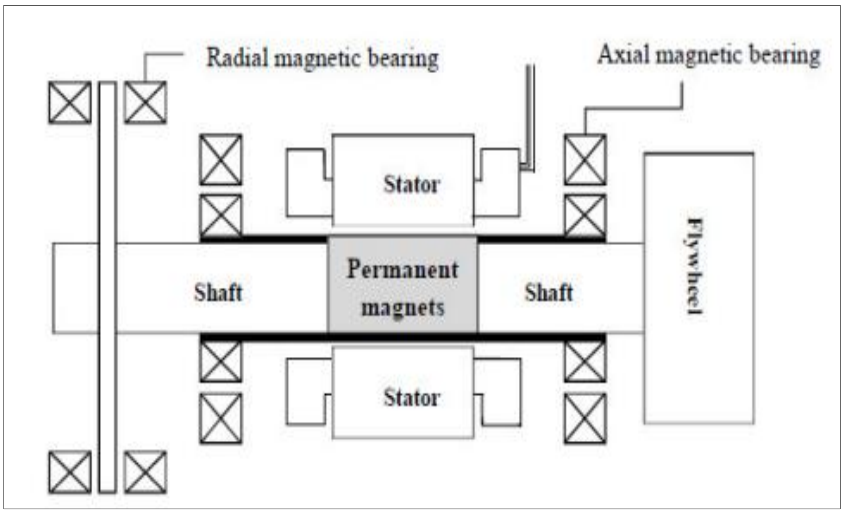

Fig 2: Synchronous motor representation

A synchronous motor for flywheel energy storage system as outlined by Ji *et al*. (2021) [7]

Applications

A constant speed and efficiency in synchronous motors offer precise application in the innovative industry:

- **Fiber production:** The areas are vital for high-precision machining tools in construction and other manual-required engagements.
- **Power factor correction in electrical grids:** The motor suits a well-articulated environmental essential to create an enabling environment for high-speed product manufacturing (Mercorelli, 2023, p. 12) [9].
- **Unlimited Integration:** The motor application suits industrial areas requiring constant speed informed by quality and expectation for the product to promote easiness.

Advantages

Synchronous motor emerges as among the best suiting power balancing factors in industrial applications with various benefits:

- High efficiency at steady-state operation.
- Capability to improve power factor in large systems.
- Suitable for both low-speed and high-speed applications.

Limitations:

Despite well-explored features and applications drawn from synchronous motors, its reliance fosters a various challenge:

- Complex construction and higher initial cost compared to induction motors.
- Requires careful maintenance for the rotor.

Servo Motors

Servo motors sustain the position, speed, and torque in industrial applications. As reliable tools, the motors typically support closed-loop control systems and excel needs requiring accurate and dynamic performance (Ali *et al*., 2020, p. 24) [2].

Features

- **Feedback mechanisms:** the motor creates an avenue for efficient information management built through encoding and integrating resolvers.
- **Alternating current capability:** the motor can convert AC or DC motors, with DC servo motors used for low-power and precise tasks.

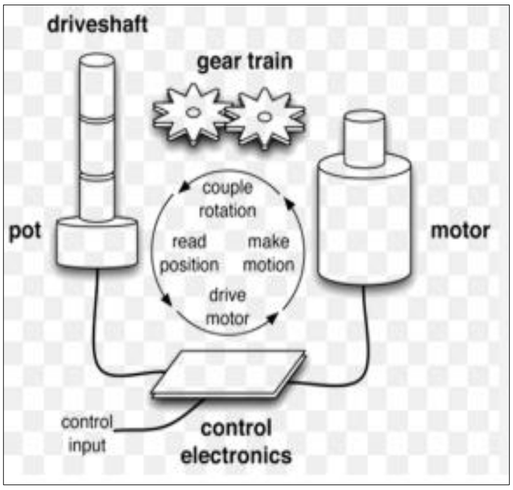

Fig 3: Servo motor guide

Typical process used in servo motor applications. Guide adopted from Ali *et al*. (2020) [2]

Applications:

Servo motors attract a diversified application in diversified areas and dynamism of innovative culture in a technological front as highlighted below:

- Robotics and automated machinery have evolved in various industries for service delivery.
- CNC (Computer Numerical Control) machines for efficient service delivery.
- Conveyor systems in packaging and material handling industries to avoid wastages and avoidable costs.

Advantages

Servo motors' growing influence in innovative designs for industrial application offers benefits to organizations identifying with dynamism in operational guided by;

- Excellent speed and position control.
- High torque at low speeds, ideal for intricate applications.
- Compact size with high power density.

Limitations:

While servo motors remain in the limelight as game-changers for the future of technological standards integration, they fall short in most areas;

- Higher cost and complexity compared to standard motors.
- Dependence on sophisticated control systems.

Different Innovative Motors Used in Industrial Applications

The evolving innovative designing approaches in the high-efficiency industry create demand for motors that deliver superior efficiency, performance, and sustainability. Dambrauskas *et al*. (2020) [5] establish the development of innovative motor designs as instrumental in exploring application levels. Most advancements in diverse motor designing address the challenges of energy consumption, precision, and adaptability in dynamic contemporary industrial environments. Various fundamental examples of innovative motors used in industrial applications offer clear direction on levels to integrate innovative culture:

Permanent Magnet Synchronous Motors (PMSMs)

The PMSMs model reduces energy losses associated with rotor currents for overall performance efficiency. Such motor encompasses a compact, reliable, and capable industrial application delivering high torque at low speeds, as instrumental for robotics, conveyors, and HVAC systems (Dambrauskas *et al*., 2020, P. 2) [5]. In an industry of advancing control systems, PMSMs promote precise speed and position regulation in operational efficiency in energy-intensive industries (Dambrauskas *et al*., 2020, P. 2) [5].

Brushless DC Motors (BLDCs)

Brushless DC Motors (BLDC) refers to an eliminating factor of mechanical commutator found in obsolete DC motors. The motor elevation to advanced innovation ensures organizations replace it with an electronic controller (Mohanraj *et al*., 2022, p. 54834) [10]. The motor innovation reduces wear and tear, increases lifespan, and provides superior efficiency and reliability in industrial applications. As such, BLDC motors typically are used in applications requiring high precision and low maintenance innovative designing, such as automated assembly lines, drones, and electric vehicles. A guaranteed ability for ability BLDC to operate at high speeds with minimal energy loss affirms its indispensable nature for industries striving for sustainability (Mohanraj *et al*., 2022, p. 54845) [10].

Axial Flux Motors

Axial flux motors' integration into industrial applications represents an inevitable shift in motor design, featuring a compact structure with shorter magnetic paths and lighter components. Unlike traditional radial flux motors, axial flux delivers higher power densities and efficiency in diverse industrial applications (Nishanth *et al*., 2021, para 1) [11]. An envisioned flat design for the motors makes them suitable for space-constrained applications in growing robotics and electric vehicle culture. Therefore, industries benefit from axial flux material usage, energy efficiency, and adaptability to various applications, harnessing sustainable production systems.

Switched Reluctance Motors (SRMs)

Lastly, the innovative industrial application relies on Switched Reluctance Motors (SRMs) relying on magnetic reluctance to generate motion, eliminating a growing need for permanent magnets or copper windings in various designed rotors (Fang *et al*., 2021, Current Regulations, p. 283) [6]. Leveraging innovative industrial applications exemplifies a robust motor integration developed on excellent thermal performance. SRMs apply in harsh industrial environments and high-speed service requirements such as compressors and pumps. However, incorporating control algorithms, in SRM designing is increasingly becoming a competitive tradition in innovative industrial applications demanding efficiency and reliability (Fang *et al*., 2021, Current Regulations, p. 283) [6].

Conclusion

The motor types used in industrial applications serve an industrial requirement for existing operational demands. The induction motors ascertain a general-purpose industrial application in the innovative culture to accommodate. The synchronous offers precise speed and power factor anticipated in dynamic industrial applications to meet market demands. The servo is essential in high-precision industrial applications for reliable motion controls in lesser demanding operations. An innovative design approach in industrial processes and motor technologies ensures progress for smart problem solutions. The differentiated motor innovative motors foster industrial-optimized performance through flexibility, energy saving, and adaptability for environmentally friendly operations.

References

1. Alberti L, Troncon D. Design of electric motors and power drive systems according to efficiency standards. IEEE Trans Ind Electron. 2020;68(10):9287-9296. DOI: http://dx.doi.org/10.1109/TIE.2020.3020028.
2. Ali AW, Razak FAA, Hayima N. A review of the AC servo motor control systems. ELEKTRIKA-J Electr Eng. 2020;19(2):22-39. DOI: http://dx.doi.org/10.11113/elektrika.v19n2.214.
3. Chenchevoi V, Kuznetsov V, Kuznetsov V, Chencheva O, Zachepa I, Chornyi O, *et al*. Development of mathematical models of energy conversion processes in an induction motor supplied from an autonomous induction generator with parametric non-symmetry. East Eur J Enterp Technol. 2021;4(8):112.

DOI: https://doi.org/10.15587/1729-4061.2021.239146.

4. Credo A, Petrov I, Pyrhönen J, Villani M. Impact of manufacturing stresses on multiple-rib synchronous reluctance motor performance. IEEE Trans Ind Appl. 2022;59(2):1253-1262. DOI: http://dx.doi.org/10.1109/TIA.2022.3207117.
5. Dambrauskas K, Vanagas J, Zimnickas T, Kalvaitis A, Ažubalis M. A method for efficiency determination of permanent magnet synchronous motor. Energies. 2020;13(4):1004. DOI: http://dx.doi.org/10.3390/en13041004.
6. Fang G, Scalcon FP, Xiao D, Vieira RP, Gründling HA, Emadi A. Advanced control of switched reluctance motors (SRMs): A review on current regulation, torque control, and vibration suppression. IEEE Open J Ind Electron Soc. 2021;2:280-301. DOI: http://dx.doi.org/10.1109/OJIES.2021.3076807.
7. Ji W, Ni F, Gao D, Luo S, Lv Q, Lv D. Electromagnetic design of high-power and high-speed permanent magnet synchronous motor considering loss characteristics. Energies. 2021;14(12):3622. DOI: http://dx.doi.org/10.3390/en14123622.
8. Khattra SK, Singh D, Dogra R. A review of energy efficient technology and carbon trading for reducing carbon emissions. Arch Curr Res Int. 2024;24(6):208-222. DOI: https://doi.org/10.9734/acri/2024/v24i6779.
9. Mercorelli P. Control of permanent magnet synchronous motors for track applications. Electronics. 2023;12(15):3285. DOI: http://dx.doi.org/10.3390/electronics12153285.
10. Mohanraj D, Aruldavid R, Verma R, Sathiyasekar K, Barnawi AB, Chokkalingam B, Mihet-Popa L. A review of BLDC motor: state of art, advanced control techniques, and applications. IEEE Access. 2022;10:54833-54869. DOI: http://dx.doi.org/10.1109/ACCESS.2022.3175011.
11. Nishanth FNU, Van Verdeghem J, Severson EL. Recent advances in analysis and design of axial flux permanent magnet electric machines. In: 2021 IEEE Energy Conversion Congress and Exposition (ECCE); 2021 Sep 26-30; Vancouver, Canada. IEEE; 2021. p. 3745-3752. DOI: http://dx.doi.org/10.1109/ECCE47101.2021.9595085.
12. Suresh K, Parimalasundar E, Kumar BH, Singh AR, Bajaj M, Tuka MB. Design and implementation of a universal converter for microgrid applications using approximate dynamic programming and artificial neural networks. Sci Rep. 2024;14(1):20899. DOI: http://dx.doi.org/10.1038/s41598-024-71916-z.