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Bottlenecks Hindering Adoption of BLDC Motor Technology

Dr. Rajashri A. Shendge[1], Mr. Abhijit B. Shendge[2]
[1] Gurunanak Institute of Management Studies.
Email: raji.sm43@gmail.com
[2] Wipro Technologies, Mumbai.
Email: abhijit.net@gmail.com

Abstract
Brushless DC (BLDC) motor technology offers numerous advantages, including improved efficiency, reliability, and performance, making it a promising solution for various applications across industries. However, despite its potential benefits, the widespread adoption of BLDC motors face several bottlenecks. This paper examines the key challenges hindering the adoption of BLDC motor technology and proposes strategies to overcome these obstacles. One significant bottleneck is the higher initial cost of BLDC motors compared to traditional motor technologies, coupled with limited awareness of their long-term return on investment. Compatibility issues and retrofitting challenges further complicate the adoption process, particularly when integrating BLDC motors into existing systems or appliances. Supply chain constraints, technical complexity, and skills gaps pose additional hurdles, requiring specialized knowledge and expertise for design, integration, and maintenance. Regulatory compliance, perception gaps, and infrastructure limitations also contribute to the slow uptake of BLDC technology. To address these challenges, collaborative efforts are needed to raise awareness, develop standardized performance metrics, and streamline regulatory processes. Investment in research and development, workforce training, and infrastructure development can help bridge skills gaps and improve the scalability and viability of BLDC motor deployments. Furthermore, initiatives to reduce costs, enhance interoperability, and build trust among stakeholders can accelerate the adoption of BLDC motor technology, unlocking its full potential to drive innovation and sustainability in various industries. By understanding and addressing the bottlenecks hindering the adoption of BLDC motor technology, stakeholders can foster a conducive environment for innovation, facilitate technology transfer, and realize the transformative benefits of BLDC motors in diverse applications and markets.

Keywords: Brushless DC, technology, adoption, bottleneck, challenges, Research, and development.

Introduction:
BLDC (Brushless Direct Current) technology refers to a type of electric motor that operates without the need for brushes to transfer electrical power to the rotor. Instead, BLDC motors use electronic commutation to control the motor's speed and direction of rotation. This electronic commutation is achieved through a controller that precisely sequences the currents in the motor's windings, thereby producing smooth and efficient rotation.
The main components of a BLDC motor include the stator (stationary part) with windings that generate the magnetic field and the rotor (rotating part) with permanent magnets. By energizing the stator windings in a specific sequence, the controller creates a rotating magnetic field that interacts with the permanent magnets on the rotor, causing it to turn.
BLDC motors offer several advantages over traditional brushed DC motors, including higher efficiency, longer lifespan (due to the absence of brushes that wear out), lower maintenance requirements, and better controllability. These characteristics make BLDC motors ideal for a wide range of applications, including automotive systems (such as electric vehicles and hybrid vehicles), industrial automation, consumer electronics, HVAC systems, and more.
Furthermore, BLDC motors are often used in conjunction with advanced control techniques such as closed-loop vector control to optimize their performance, enhance efficiency, and provide precise speed and torque control. Overall, BLDC technology represents a significant advancement in electric motor design and is increasingly becoming the preferred choice for various applications requiring high efficiency, reliability, and precision control.
However, despite their evident advantages, the widespread adoption of BLDC motor technology faces several bottlenecks, impeding its full realization of potential. Understanding these bottlenecks is crucial for devising strategies to overcome them and fostering the accelerated integration of BLDC motors across diverse sectors.

Review of Literature:

Tze-Yee Ho, Cong-Khoi Huynh et al 2020,published that ,the application of sensor less motor drive technology for Brushless Direct Current (BLDC) motors with wye-connected windings has gained significant traction in practical settings, offering solutions to the limitations associated with Hall sensors-based motor drives. This research contributes significantly to advancing sensor less motor drive technology, particularly in extending its applicability to delta-connected BLDC motors, where traditional sensor-based approaches face limitations. The findings of this study underscore the potential benefits of sensor less control schemes and pave the way for their wider adoption in diverse practical applications.

Dileep Kumar and R.A. Gupta, August 20, 2021 says that Brushless direct current (BLDC) motor drives have gained more popularity and emerged as a latest research area due to their ability to offer salient features such as compact size, higher efficiency, less maintenance, rugged operation, more reliable, and high torque to weight ratio. Recently, BLDC motor drives are widely adopted in numerous fields of industries and household applications such as robotics, electric vehicle, defence, aviation, industry, ventilation, dryer, and refrigerators. Moreover, rectangular phase currents are required to produce constant torque. However, BLDC motor drives are facing great challenge of current ripples due to the unequal rate of incoming and outgoing phase current during the commutation process. In view of these aspects, this paper presents a comprehensive review on BLDC motor drive. Different converter topologies and current/torque control techniques are carried out to verify potential of BLDC motor drives.

Deepak, M & Arul David, Ranjeev & Verma et al, 2022 Brushless direct current (BLDC) motors are mostly preferred for dynamic applications such as automotive industries, pumping industries, and rolling industries. It is predicted that by 2030, BLDC motors will become mainstream of power transmission in industries replacing traditional induction motors. Though the BLDC motors are gaining interest in industrial and commercial applications, the future of BLDC motors faces indispensable concerns and open research challenges. Considering the case of reliability and durability, the BLDC motor fails to yield improved fault tolerance capability, reduced electromagnetic interference, reduced acoustic noise, reduced flux ripple, and reduced torque ripple. author in conducting this survey of addressing the critical challenges of BLDC motors. Furthermore, comprehensive study on various advanced controls of BLDC motors such as fault tolerance control, Electromagnetic interference reduction, field orientation control (FOC), direct torque control (DTC), current shaping, input voltage control, intelligent control, drive-inverter topology, and its principle of operation in reducing torque ripples are discussed in detail.

P. Sridevi,J. S.ShrinaMaggi,et al , This research delves into strategies for enhancing the efficiency of ceiling fans, a significant contributor to household power consumption, particularly in warm-climate developing regions. By leveraging existing technologies, it proposes achievable solutions that could potentially increase ceiling fan efficiency by up to 60%. If implemented globally by 2025, these upgrades could conserve approximately 80 TWh/year of electricity, leading to a reduction of 30 million metric tonnes of Carbon Dioxide emissions annually. The study also examines the effectiveness of various policies and programs, such as energy efficiency standards and consumer labeling, in promoting the adoption of energy-efficient ceiling fans. Additionally, it explores the benefits of integrating Brushless DC Motors (BLDC) in ceiling fans, highlighting the potential for improved energy conservation through linear relationships between current-to-torque and voltage-to-rpm.

Objectives:

1. To understand BLDC motor adoption in various sectors
2. To analyse the bottleneck hindering adoption of BLDC motor technology

Hypothesis:

BLDC motor adoption in home appliances sector is hindered by cost factor

Scope of the Research:

Study is limited only to home appliances sector. Home appliances taken into consideration for study are as follows. Vacuum Cleaner, Mixer, Household Fans, Refrigerator and Air Conditioner

Research Methodology:

- **Methodology:** Survey of shopkeepers (Sellers) selling BLDC motor home appliances was conducted to understand adoption of BLDC technology by customers. Structured questionnaire was framed, and responses were collected from the sellers. Interviews were conducted onsite.
- **Sample:** Responses were collected from shopkeepers selling BLDC motor home appliances
- **Sample Size:** 612 shopkeepers were surveyed from Central Mumbai from Dadar to Kalyan

Data Analysis:

Analysis of data is done using statistical tool and for hypothesis testing chi square test is applied.

Data Analysis:

Customer Awareness of BLDC Motor Technology

Awareness	**Reponses**	**Percentage**
Not at all aware	158	25.4
Slightly aware	148	23.8
Moderately aware	229	36.9
Very aware	59	9.5
Extremely aware	27	4.3
Total	**612**	**100**

Interpretation: Over 25% of customers visiting appliance stores for home appliances purchases are unfamiliar with BLDC technology.

Customer Awareness of BLDC Technology Features

Awareness of Feature	**Reponses**	**Percentage**
Not at all aware	51	11.02
Slightly aware	61	13.17
Moderately aware	222	47.95
Very aware	81	17.49
Extremely aware	48	10.37
Total	**463**	**100**

Interpretation: Out of 75% customer who are aware of BLDC technology from it around 11 percent are just know to it that some BLDC technology exist

Customer Interest in Energy Efficiency

Interest in Energy Efficiency	**Reponses**	**Percentage**
Not interested at all	0	0.00
Slightly interested	48	7.84
Moderately interested	68	11.11
Very interested	234	38.24
Extremely interested	262	42.81
Total	**612**	**100**

Interpretation: Every customer shopping for home appliances prioritizes energy efficiency as a key consideration.

Customer Inquiry Rate for BLDC Appliances

Inquiry Rate for BLDC	Reponses	Percentage
more than 55%	301	57.02
40% to 55%	148	29.37
25% to 40%	47	10.15
less than 25%	12	3.46
Total	**463**	**100**

Interpretation: It is observed that 57% of people inquire about BLDC technology at the rate of 57%

Inquire for BLDC Appliances by Customers:

Preferred BLDC Appliances	Reponses	Percentage
Vacuum Cleaner	68	14.69
Mixer	28	6.05
Household Fans	182	39.31
Refrigerator	109	23.54
Air Conditioner	76	16.41
Total	**463**	**100**

Interpretation: It is observed that inquire for fan, refrigerator and Ac is more compare to mixer and vacuum cleaner

Customer Intention to Purchase BLDC Appliances vs. Cost Concerns:

Cost Concern	Reponses	Percentage	Rank
more than 55%	278	60.04	1
40% to 55%	101	21.81	2
25% to 40%	59	12.74	3
less than 25%	25	5.40	4
Total	**463**	**100**	

Interpretation: Cost is the major constraint that hampers adoption of BLDC technology by customer for home appliances

Trust Factor in Purchasing BLDC Appliances:

Trust Factor	Reponses	Percentage
more than 55%	182	39.31
40% to 55%	178	38.44
25% to 40%	68	14.69
less than 25%	35	7.56
Total	**463**	**100**

Interpretation: Trust is a major issue about 39% people don't adopt BLDC technogy due to trust factor

Customer Concerns about After-Sales Service:

After Sales Service	Reponses	Percentage
more than 55%	196	42.33
40% to 55%	172	37.15
25% to 40%	58	12.53
less than 25%	37	7.99

Total	436	100

Interpretation: More than 42% customer are apprehensive about after sales service and hence they don't go for BLDC

Hypothesis Testing:

To determine if the calculated chi-square value is statistically significant, we need to compare it to the critical value from the chi-square distribution with 3 degrees of freedom.

At a typical significance level of 0.05, the critical value for a chi-square distribution with 3 degrees of freedom is approximately 7.815.

Since our calculated chi-square value (74.60) far exceeds this critical value, we reject the null hypothesis.

Now, we have both the observed and expected frequencies for each category. We can proceed to calculate the chi-square statistic:

$\chi 2=\sum(O-E)2E\chi 2=\sum E(O-E)2$

Let's compute the chi-square value using these values.

$\chi 2\approx 74.60$

Conclusion:

1. BLDC motors typically use strong permanent magnets on the rotor, which currently require rare-earth metals such as neodymium. The rarity and high demand for these materials make them expensive.
2. Since BLDC technology is not widely known, many people are uncertain about the lifespan and performance of the features it promises.
3. As a new technology, there are concerns about the availability and quality of after-sales service.
4. In the home appliances sector, customers show the most interest in fans and refrigerators.
5. Cost is a major concern that hinders the purchase of home appliances by many people.

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