# Utilization of Printed Circuit Board (PCB) in Axial Flux Machines: A Systematic Review

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## 01. Abstract

This study reviews the role of PCBs in axial flux permanent magnet machines (AFPMMs), analyzing 38 articles from 2019 to 2024 using the PRISMA methodology. PCBs are vital for lightweight AFPMMs, particularly in single stator double rotor (SSDR) configurations, optimized using tools like ANSYS and COMSOL. Concentrated trapezoidal winding is the dominant topology, with growing interest in DSSR and multi-disk designs. The findings highlight advancements in PCB manufacturing, winding optimization, and defect mitigation, emphasizing their evolving role in future AFPMM innovations.

## 02. Introduction

- The growing need for energy-efficient, electric machines [1], [2], [3].
- Coreless Axial Flux Permanent Magnet Machines (CAFPMMs)
- CAFPM design is the incorporation of Printed Circuit Boards (PCBs) for executing winding configurations
- Innovative devices employ single-layer PCB designs for both the stator and rotor, creating a lightweight and streamlined configuration.
- Single stator single rotor (SSSR), single stator double rotors (SSDR), Double stators single rotor (DSSR), Multi stators Multi rotor (MSMR).

## 03. Objectives

- To Assess advancement in PCB design/defect strategies.
- To evaluate the Electromagnetic impact of PCB winding.
- To study the influence of thermal /losses.

## 04. Adapted Methodology

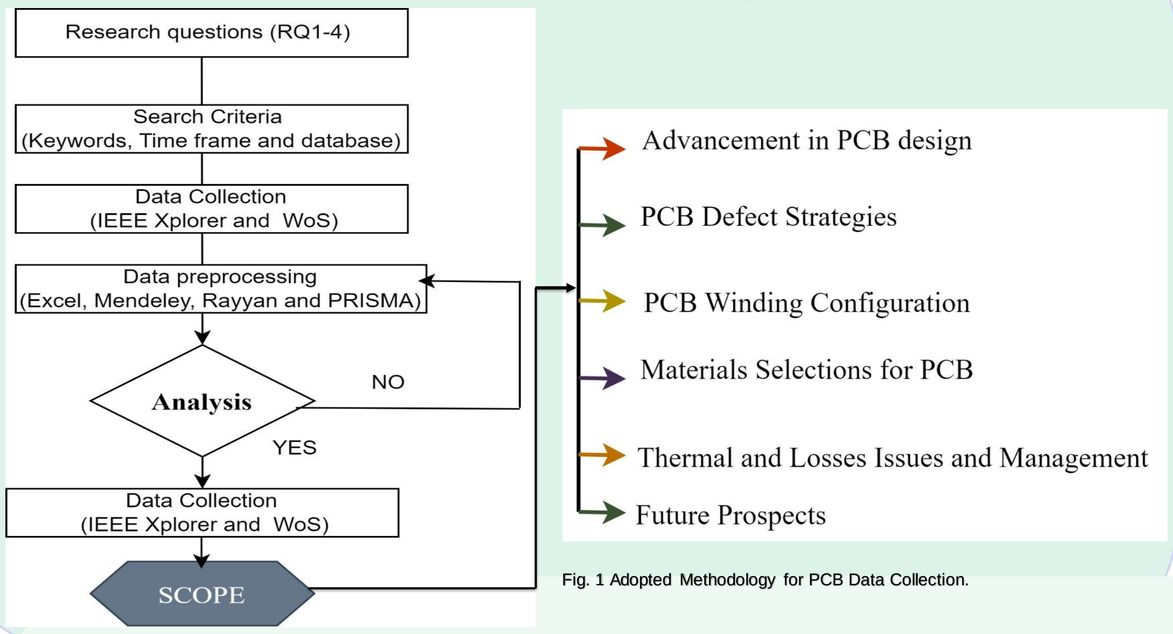



Fig. 1 Adopted Methodology for PCB Data Collection.

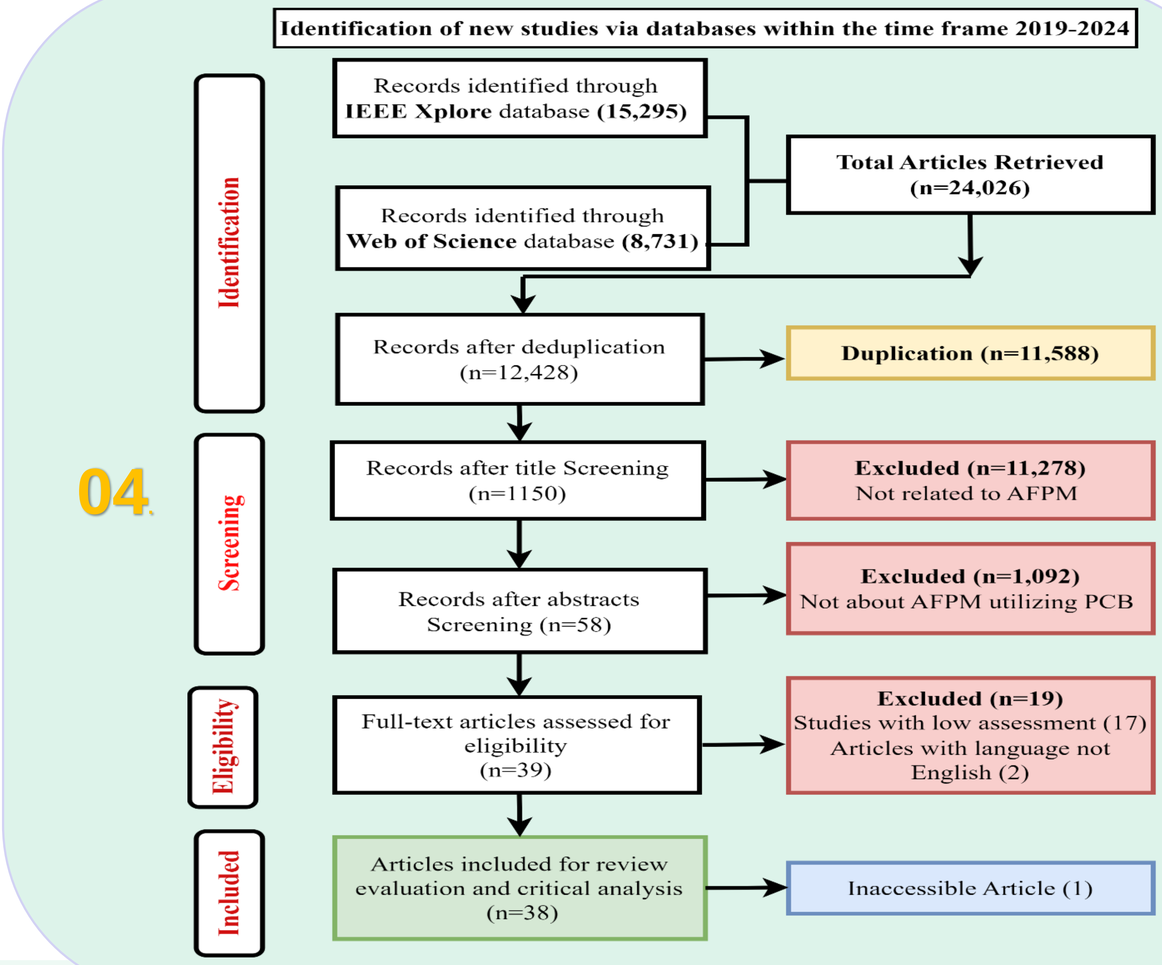
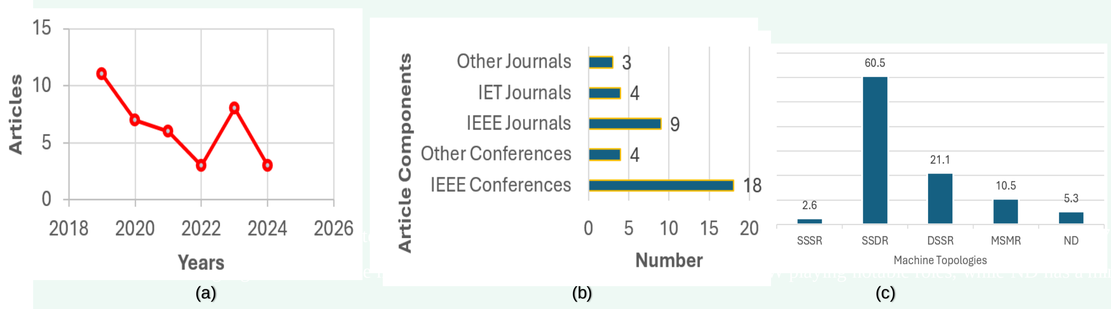



Fig. 2 PRISMA Analysis for Data Cleaning and Extraction.

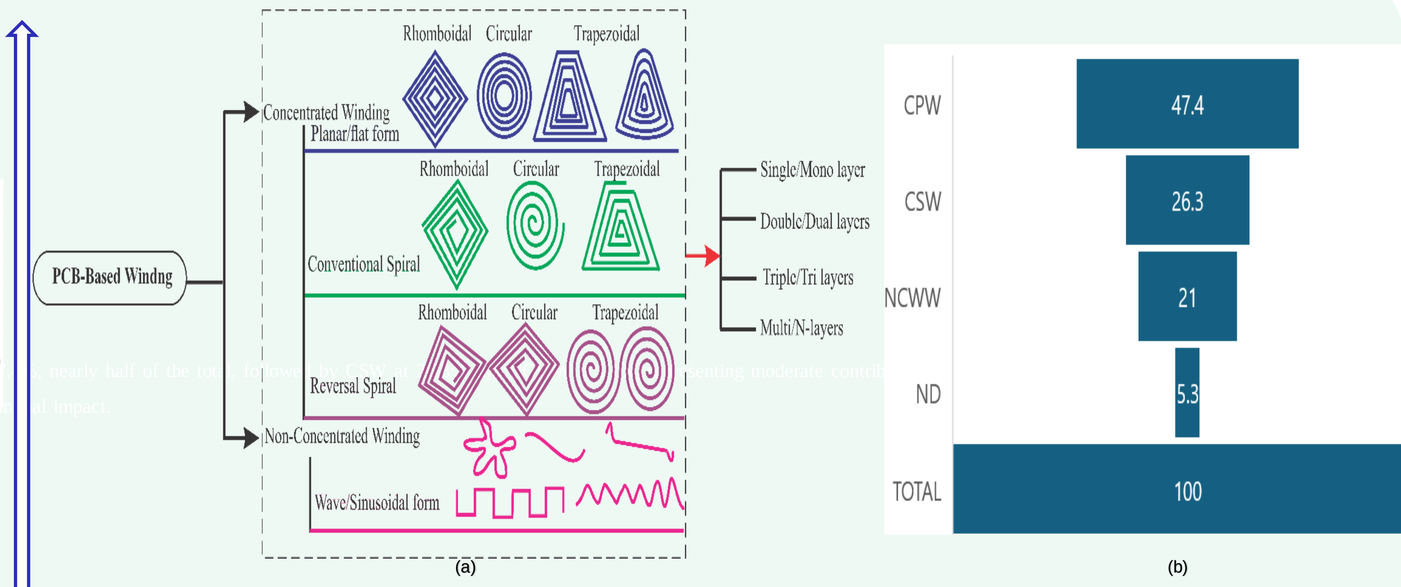
## 05. Results and Discussion




(a) (b) (c)

Fig. 3 Adopted Methodology for PCB Data Collection.

- Figure 3(a) reflecting dynamic shifts in scholarly focus and priorities from 2019-2024 with peak at 2019and decline in 2022 and 2024 respectively.
- Fig. 3(b) shows a strong preference for IEEE platforms in AFPMMs research .
- Fig. 3(c) reveals SSDR AFPMMs dominates machine topology contributions with 60.5%, DSSR at 21.15% While MSMR , SSSR and ND contribute 10.5%, 2.6% and 5.3% respectively.




(a) (b)

Fig. 4 (a) Winding configurations: CPW: Contrated Planar winding, CSW: Concentrated Spiral winding, NCWW: Non-Concentrated Wave winding, ND: Not defined (b) Percentage contribution of each winding.

- Fig. 4(a) present three adopted winding topologies as Planar windings, Concentrated spiral winding and non-concentrated wave winding with their subsequent variants and performances.
- Fig. 4(b) funnel chart illustrates the proportional contributions of four categories, totaling 100%. CPW dominates with 47.4%, nearly half of the total, followed by CSW at 26.3% and NCWW at 21%, representing moderate contributions. ND accounts for the smallest share at 5.3%. This distribution highlights CPW as the most significant contributor, with CSW and NCWW playing notable roles, while ND has a minimal impact.

## 06. Conclusion

1. **Lightweight AFPMMs with PCB components demonstrate enhanced power quality and electromagnetic performance.**
2. **Concentrated trapezoidal winding dominates, followed by distributed winding designs.**
3. **SSDR coreless AFPM machines are mostly priotized and optimized for defects and losses using tools like ANSYS and COMSOL.**

## 07. References

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