International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Applications of Power Electronics using AI Technology: Overview

Karuna Gamare[1], V. A. Joshi[2]

[1]Lecturer, Instrumentation, VPM's Polytechnic, Thane
[2]HOD, Instrumentation, VPM's Polytechnic, Thane

Abstract
In this century our world, there are huge impacts of AI. This paper discusses an overview of the Artificial Intelligence (AI) applications used in power electronic systems. AI works in three distinctive life-cycle phases, design, control, and maintenance. Also, it includes optimisation, classification, regression, and data structure exploration. Here we discuss, the applications of four categories of AI: expert system, fuzzy logic, metaheuristic method, and machine learning. This paper shows various techniques of AI, applications of AI and different methods are fault diagnosis and prognosis. Future scope of AI in power electronics is discuss in this review paper.

Keywords - Artificial intelligence, design, Fuzzy logic, Expert System, fault diagnosis, power electronic.

1. Introduction

Artificial Intelligence (AI) is rapidly growing and last several decades it has been one of the most researched areas [1], [2]. AI aim is not to provide facilitate systems but also intelligence in learning and reasoning that is capable as human. It has lots of advantages and has been successfully applied in industrial areas such as image processing, speech recording, autonomous cars, computer vision, etc. In power electronics gets various benefits from the AI. There are various applications, including intelligent controller for multi-colour light-emitting diode (LED) [3], maximum power point tracking (MPPT) control for wind energy conversion systems [4], [5], anomaly detection for inverter [6], etc. By implementing AI, power electronic systems are embedded with capabilities of self-awareness and self-adaptability and therefore the system autonomy can be improved.

AI has used as a powerful tool for increasing the performance as well as the functionality of power electronics system [7]. Using AI in these systems, it gives advantages like improved efficiency, reliability, fault detection, and energy management. Traditional methods are difficult to analysis and modelling of complex systems also can't easily allowing the identification of patterns and correlations but AI algorithms do it easily. In power electronics and drive systems, AI can be used to control, real-time monitoring, enabling intelligent decision-making and predictive maintenance. Also, AI algorithms detects any faults before system failure, reducing maintenance costs and improving system uptime.

2. Methods of AI for Power Electronics

In computer science, Artificial Intelligence (AI) is used to develop algorithms and systems. To perform

tasks, they need human intelligence. In power electronics and drive systems there are several AI techniques, including Expert Systems, machine learning, fuzzy logic, and metaheuristic methods, etc.

A) Expert System:

In AI, the Expert system is the effectively implement method that is used in industrial applications [8]. It is based on IF-THEN rules. It is work on database that integrates the expert knowledge in a Boolean logic catalogue. This is an intelligent system. Simulation process is based on the database that answer come in the why-and-how inquires. With the help of field expert experience or simulation data, facts, and statements database is well form. This method is replaced with other AI methods e.g. ML, Fuzzy logic because they have advance capabilities interface and high accuracy.

B) Machine learning:

AI's subset is Machine learning. Machine learning algorithms can make predictions or decisions based on the analysis of correlations in data and identify different patterns. It involves the development of algorithms that enable computers to learn from data. In control and optimization, fault diagnosis, energy management, etc. used ML algorithm technique.

C) Fuzzy logic:

To enable computers uncertainty and imprecision are used by mathematical techniques that are known as fuzzy logic [9]. It involves representing data using linguistic variables, such as "hot" or "cold," and then applying logical rules to these variables to make decisions. Fuzzy logic can be used for applications such as control and optimization, fault diagnosis, and energy management.

D) Metaheuristic methods:

This method is an optimization algorithm method. These methods are inspired by natural processes like evolution or swarm behaviour. Traditional methods were not effective at that time, Metaheuristic methods are used to solve complex optimization problems. Metaheuristic methods can be used for applications such as power electronics design and optimization, and energy management.

3. Difference between above AI Techniques for Power Electronics

AI-based control techniques have lots-off benefits for power electronics. Technique advantages, disadvantages and its uses shown in Table 1.

Table 1: AI technique with advantages, disadvantages and its uses

Technique of AI	Advantages	Disadvantages	Uses
Machine learning	- learn from data - improve performance over time - handle large amounts of data	- Requires high-quality data for training, - Suffer from overfitting or bias, - Difficult to interpret	- Collect more data to improve model performance, - to prevent overfitting - to explain model behaviour

Fuzzy logic	- handle uncertain information - representing human knowledge and expertise, - handle nonlinear systems	- Difficulty in determining the appropriate membership functions and rules - lack of scalability	- to inform the design of membership functions and rules, - explore hybrid approaches with other AI techniques for scalability
Metaheuristic methods	- with non-linearity handle complex optimization problems constraints - quickly converge to good solutions - handle multiple objective functions	- Lack of guarantees of global optimality, - require significant computational resources, sensitivity to parameter settings	- to improve the probability of finding good solutions - develop customized metaheuristic algorithms for specific applications

AI have different challenges but with the help algorithms it can be solved. Algorithm have most challenging things that they have to find any problem
and then solved or correct that problem between the large data. If algorithm is not well trained then this process is time-consuming and expensive.

4. AI Use for Fault Diagnosis in Power Electronics

Power electronics systems are exposed to faults because their complexity and harsh operating by anyone. In power electronics, AI techniques such as machine learning and deep learning are used to detect and predict faults in components. This section describes the applications of AI for fault diagnosis and prognosis and different techniques for detecting and predicting faults in power electronics.

- **Applications of AI for Fault Diagnosis and Prognosis**: AI-based techniques have been used for fault diagnosis and prognosis. These techniques are help to detect faults at early stage and predict their life as well as future behaviour. Here, we discuss some power electronics applications of AI for fault diagnosis and prognosis as follows:
  a. Fault detection in converters, IGBTs, MOSFETs, motors and generators etc.
  b. Prognosis of components such as capacitors, inductors and other mechanical components.

- **Different Techniques for Detecting and Predicting Faults in Power Electronics:** In power electronics, different AI techniques have been used for detecting and predicting faults. Machine learning, deep learning, fuzzy logic, etc. are the techniques used for fault detection and prognosis in power electronics here we discuss some of them.
  a. Fuzzy logic: It has been used for fault detection in converters, IGBTs and MOSFETs, etc.
  b. Expert systems: In this technique use a knowledge to solve problems.
  c. Artificial Neural Networks (ANNs): It is a type of deep learning algorithm. ANNs have been used for fault detection in electric machines such as motors and generators.
  d. Support Vector Machines (SVMs): These are machine learning algorithms. SVMs have been shown to be effective in detecting faults in IGBTs and MOSFETs.

5. Future Scope of Direction in AI for Power Electronics

From few years AI has been use for control, fault diagnosis and design. In power electronics there are some advance technology in the use of AI includes:

- Deep learning techniques: In power electronics, this technique has been used for fault diagnosis and prognosis, energy management, and control.
- Reinforcement learning: This method has been applied for control of power electronics systems, including motor drives, converters, and inverters.
- Edge computing: Edge computing has been used for real-time control of power electronics systems.
- Hybrid AI techniques: This technique is combination of fuzzy logic and genetic algorithms.

6. CONCLUSION

In this paper, we give a review on the current state of Artificial Intelligence (AI) in power electronics systems. This paper analysed the various techniques of AI, applications of AI and different methods are fault diagnosis and prognosis. We saw various AI techniques and tools that have been developed for power electronics systems, there strengths, challenges and limitations. The review examined that AI technology has been trend in various field such as the organic electronics, Internet of Things (IoT) and 5G.

Reference

1. C. M. Bishop, Pattern Recognition and Machine Learning. Springer, 2006.
2. I. Goodfellow, Y. Bengio, and A. Courville, Deep Learning. MIT Press, 2016.
3. X. Zhan, W. Wang, and H. Chung, “A neural-network-based colour control method for multi-colour LED systems,” IEEE Trans. Power Electron., vol. 34, no. 8, pp. 7900–7 913, Aug. 2019.
4. C. Wei, Z. Zhang, W. Qiao, and L. Qu, “Reinforcement-learning-based intelligent maximum power point tracking control for wind energy conversion systems,” IEEE Trans. Ind. Electron., vol. 62, no. 10, pp. 6360–6370, Oct. 2015.
5. C. Wei, Z. Zhang, W. Qiao, and L. Y. Qu, “An adaptive network-based reinforcement learning method for MPPT control of PMSG wind energy conversion systems,” IEEE Trans. Power Electron., vol. 31, no. 11, pp. 7837–7848, Nov. 2016.
6. I. Bandyopadhyay, P. Purkait, and C. Koley, “Performance of a classifier based on time-domain features for incipient fault detection in inverter drives,” IEEE Trans. Ind. Informat., vol. 15, no. 1, pp. 3–14, Jan. 2019.

7. Dr. K. Vasudevan, APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN POWER ELECTRONICS AND DRIVES SYSTEMS: A COMPREHENSIVE REVIEW, Journal of Power Electronics (JPE), Volume 1, Issue 1, January-December 2023,
8. A. Mellit and S. A. Kalogirou, "Artificial intelligence techniques for photovoltaic applications: A review," Progress Energy Combustion Sci., vol. 34, no. 5, pp. 574–632, Oct. 2008.
9. B. K. Bose, "Artificial intelligence techniques in smart grid and renewable energy systems-some example applications," Proc. IEEE, vol. 105, no. 11, pp. 2262–2273, Nov. 2017.