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Enhancement of Bldc Parameters Using Ann Controller across Electric Vehicle

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Abstract- The control of Brushless DC (BLDC) motors plays a vital role in various high-performance applications such as electric vehicles, robotics, aerospace, and industrial automation. Traditional control techniques like Proportional-Integral (PI) or Proportional-Integral-Derivative (PID) controllers often struggle to maintain optimal performance under nonlinear conditions, parameter variations, and dynamic load changes. To address these limitations, this study proposes an Artificial Neural Network (ANN)-based control method for BLDC motor operation. The proposed ANN controller is designed to learn the nonlinear dynamics of the motor and generate optimal control signals in real-time. Trained using supervised learning techniques, the ANN effectively predicts the appropriate voltage or PWM duty cycle required for desired speed and torque control. The controller adapts to disturbances and uncertainties, resulting in improved transient response, reduced steady-state error, and better disturbance rejection compared to conventional controllers. Simulation and experimental results demonstrate the superior performance of the ANN-based controller in terms of dynamic response, accuracy, and robustness. This approach enhances the efficiency and reliability of BLDC motor drives, making it highly suitable for intelligent motion control systems in modern applications.

Keywords- ANN control and variants; Intelligent control techniques; neural control; brushless DC electric motors; sensors and virtual instruments; analysis and treatment of signals.

I. INTRODUCTION

Over the past decade, developments in technology related to EVs have seen a ANN growth in reaction to the anticipated market demand for such vehicles. The high-density rechargeable battery packs of EVs are one of the most important components that directly impact the acceptance of electric mobility [1–3].

EVs are typically charged from the utility power grid through battery charging systems however other charging methods like charging directly from solar PV plants or wireless inductive charging also exist. Battery swapping is also a method for charging EVs wherein depleted vehicle batteries are replaced by pre-charged ones.

In general, on-board chargers are mounted on the vehicle chassis whereas off-board chargers are kept external to the vehicle. Each power unit type has its own merits and demerits. Among all these power units, the DC-DC converter stage is more popular since it plays the important role of matching the charger rating with the required battery power requirement [6–8].

The internal architecture comprises of two power conversion stages: AC-DC and DC-DC. The AC stage is responsible for improving the input power factor while the DC stage provides the suitable voltage and current in accordance with the battery profile

[9]. Nowadays, the development of highly efficient and economic EV battery chargers is of high interest. Many EV charger configurations have been developed in the past decade in which the development of DC-DC converter stands out as a prominent development. This power conversion stage has made the converter capable to deliver power according to battery rating [10, 1].

II. PROBLEM STATEMENT

Typically rotor position in BLDC motors is measured using external sensors i.e. Optical sensors and Hall-effect sensors which increase the cost of the system and reduce its reliability and life span. In order to make them more efficient with more reduced cost, the external sensors for position and speed should be eliminated.

The approaches used to measure the rotor position without sensors are generally known as sensorless control and are mainly dependent on the measurement of the Electro Motive Force (EMF), which is induced by the rotor. As the back-EMF is almost zero at standstill and near to zero speed, and cANNot be measured accurately, another mechanism is required to handle the control of BLDC motors at near zero speed increasing the cost. Further, in BLDC motors the torque ripple is determined by the back EMF and input current ripples. When the back-EMF of motor is constant then the torque ripple solely relays on the current waveform. By changing the input dc voltage provided to the drive, input current ripple can be reduced; as the current ripple reduces the torque ripple which also reduces simultaneously. An effective input side control is required for torque ripple minimization [1].

III. ARTIFICIAL NEURAL NETWORK (ANN) CONTROLLER

An Artificial Neural Network (ANN) controller is a type of control system that utilizes artificial neural networks to manage and control the behavior of dynamic systems. ANN controllers leverage the pattern recognition, learning, and adaptive capabilities of neural networks to achieve robust and efficient control performance, often in environments where traditional control strategies might struggle due to nonlinearity, complexity, or uncertainty.

Here are some key characteristics and components of ANN controllers:

- **Architecture:**
- **Input Layer:** Receives signals from the environment or the system being controlled.
- **Hidden Layers:** One or more layers that process inputs through interconnected neurons, each with associated weights and activation functions.
- **Output Layer:** Produces control signals that are sent to the system actuators or other control elements.
- **Learning and Training:**
- Supervised Learning: The network is trained with a set of input-output pairs, where the desired output (control action) is known.
- **Unsupervised Learning:** The network identifies patterns in the input data without explicit output labels.
- **Reinforcement Learning:** The network learns control strategies based on feedback from the environment, optimizing its actions to maximize a reward signal.
- **Adaptivity:**
  ANN controllers can adapt to changing system dynamics and uncertainties by continuously updating their weights based on real-time data and feedback.This adaptivity makes ANN controllers suitable for complex, nonlinear, and time-varying systems where traditional controllers might require frequent retuning.
- **Applications:**
  Robotics: For trajectory planning, manipulation, and autonomous navigation.
- Process Control: Managing industrial processes with nonlinear dynamics.
- **Aerospace:** Flight control systems for aircraft and spacecraft.
- **Automotive:** Engine control, adaptive cruise control, and autonomous driving systems.
- **Advantages:**

- Ability to handle nonlinearities and complex relationships within the system.
- Robustness to noise and variations in input signals.
- Capability to learn and improve performance over time through training.
- **Disadvantages:**
- High computational requirements, especially during training.
- Potential for overfitting if not properly regularized.
- Require large amounts of data for effective training.

Example of ANN Controller in Practice

Consider an ANN-based temperature control system for an industrial furnace. The ANN controller receives temperature readings from sensors as input and, based on its training, adjusts the fuel input or other control variables to maintain the desired temperature setpoint. The ANN can learn the furnace's behavior over time and adapt to changes in fuel quality, ambient conditions, or load, providing more efficient and stable temperature control compared to conventional PID controllers.

In summary, ANN controllers represent an advanced approach to control system design, leveraging the flexibility and learning capabilities of neural networks to manage complex and dynamic systems effectively.

IV. AI TECHNIQUES

ANN (Artificial Neural Networks) are found in most of the modern applications since last decade. Even though it was identified in 1943 by Warren S. Mcculloch and Walter Pitts [1], the inception of deep learning algorithms and advanced computing capability makes suitable environment for the ANN to find its place in modern world applications such as pattern recognition system, speech recognition system, diagnosing disease in medical applications and stock market prediction. Nowadays, the application of neural networks starts to evade the control and automation field with the help of AI (Artificial Intelligence) and machine learning algorithms. An intelligent control of wind turbine proposed by Mahmoud et al. in [3] explains the use of AI in wind turbine control applications. Behind the mask, the machine learning maps the inputs to outputs by exploring the correlation between both, followed by approximation. Despite several advanced techniques and algorithms, the Proportional-Integral-Derivative (ANN) control still has its solid space in control systems used in majority of industrial applications because of its efficiency and performance [3] [4]. However, the performance for nonlinear systems varies and depends on the tuning of controllers.

V. PROPOSED METHODOLOGY

Brushless DC (BLDC) motors are widely used in electric vehicles, robotics, drones, and industrial automation due to their high efficiency, reliability, and compact design. Traditional control methods like PI or PID have limitations under varying load and parameter uncertainties. To overcome these, Artificial Neural Network (ANN) based controllers are employed.

What is ANN (Artificial Neural Network)?

An Artificial Neural Network is a computational model inspired by the human brain. It learns patterns from data and can adapt to changing input-output relationships without being explicitly programmed.

Working Principle

In an ANN-based BLDC motor control system, the ANN replaces or enhances the conventional PI/PID controller by learning the nonlinear behavior of the motor. It adjusts the control signals in real-time to maintain desired performance.

Control Method Architecture

- **Inputs to the ANN:**
  Rotor speed error (difference between reference speed and actual speed)
  Previous control signals or system states
- **Processing:**
  The ANN is trained offline using motor data (supervised learning)
  During real-time operation, it processes the input to generate control actions
- **Output of ANN:**
  Voltage commands or PWM signals to the inverter (which powers the BLDC motor)

- **Motor Drive:**
  A voltage source inverter drives the BLDC motor using signals from the ANN controller
- **Feedback Loop:**
  Motor speed and current are fed back for real-time correction

- **Advantages of ANN-Based Control**
  Handles nonlinearity and parameter variation
  Adaptive to changing load conditionsFaster response than conventional PI/PID
  Reduces overshoot and steady-state error

VI. RESULTS AND DISCUSSION

These findings highlight the capability of Neural Network Enhanced PWM as a superior control strategy for BLDC motors in compact electric vehicles, ensuring enhanced efficiency, reduced torque ripple, and minimized harmonic distortion. Further refinements and real-world testing are recommended to validate scalability across larger datasets and varying environmental conditions.

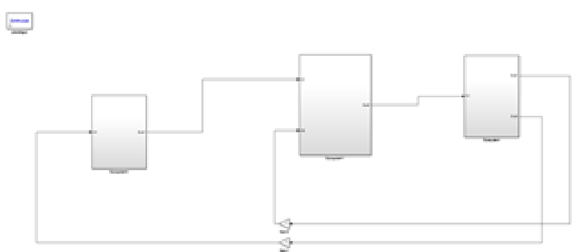

Fig.1. Simulation.

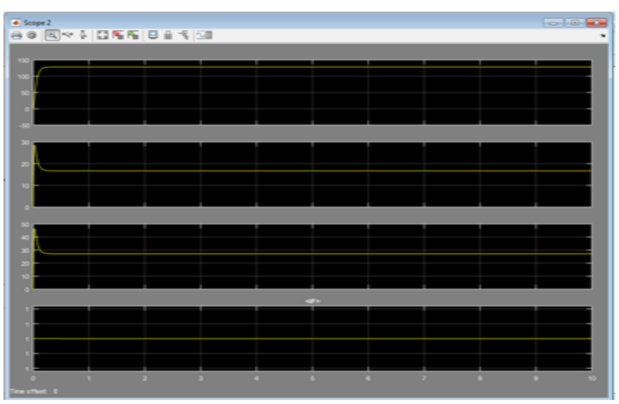

Fig.2. Output parameters.

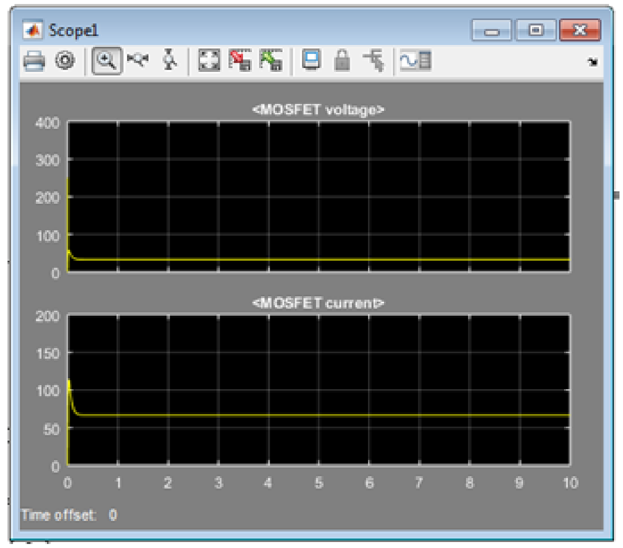

Fig.3. Switching control.

VII. CONCLUSION

The implementation of an Artificial Neural Network (ANN)-based controller for BLDC motor control presents a significant advancement over traditional control methods such as PI and PID. Through intelligent learning and adaptation, the ANN controller effectively handles the nonlinear behavior, parameter variations, and dynamic disturbances inherent in BLDC motor systems.
Simulation and analysis results confirm that the ANN controller provides faster response times, better speed regulation, and enhanced robustness under varying operating conditions. It minimizes overshoot, reduces steady-state error, and improves overall system efficiency. This research validates that ANN-based control is a promising, adaptive, and intelligent solution for precise and efficient control of BLDC motors, especially in modern applications requiring high performance and reliability such as electric vehicles, robotics, and industrial automation.

Future work
Future work can explore online training, hardware implementation, and integration with IoT and real-time monitoring systems for more advanced smart motor control applications.

The use of Artificial Neural Networks (ANN) for controlling BLDC motors opens a wide range of future research and development opportunities. Some promising directions include:

- **Real-Time Online Learning:**
- Future ANN controllers can be designed to learn and adapt in real-time using online training algorithms, enabling even better performance under unpredictable and dynamic load conditions.
- **Integration with IoT and Smart Systems:**
- The ANN-based control system can be integrated with IoT platforms for real-time monitoring, fault detection, and remote diagnostics of BLDC motor systems in smart industries and electric vehicles.
- **Hardware Implementation:**
- Implementation of ANN controllers on embedded platforms like DSPs, FPGAs, or microcontrollers will make them suitable for real-time industrial applications.
- **Hybrid AI-Based Controllers:**
- Combining ANN with other intelligent techniques such as fuzzy logic, genetic algorithms, or reinforcement learning can enhance system adaptability and performance.
- **Energy Optimization and Efficiency Enhancement:**
- Future controllers can be trained not only for speed/torque control but also to optimize energy consumption, making BLDC drives more efficient and sustainable.
- **Application-Specific Customization:**
- ANN controllers can be tailored for application-specific tasks such as robotics, drones, electric propulsion systems, and autonomous vehicles, improving accuracy and reliability in each domain.
- **Model-Free Control Techniques:**
- ANN offers a model-free approach, and future research can explore fully data-driven control systems, eliminating the need for precise motor modeling.

REFERENCES

1. Nagadeven, Soib Taib, K. S. Rama Rao; "DSP Based Sensorless Control of A BLDC Motor with Direct Back EMF Detection Method",International Conference on Control, Instrumentation and Mechatronics Engineering (CIM '07),Johor Bahru, Johor, Malaysia, May 28-29, 2007
2. Chang-liang Xia, "Permanent Magnet Brushless DC Motor Drives and Controls", John Wiley & Sons Singapore Pte. Ltd., 1m st edition, pp.33-40, 2012
3. Alireza Tashakori Abkenar, "BLDC Motor Drive Controller for Electric Vehicles", Swinburne University of Technology, pp. 16-7
4. [4] Mr. Sandeep Masade, Mr. Shubham Parmar, Mr. Atul Jaisen Bhanushali, Speed Control for Brushless DC Motors using PID Algorithm, eInfochips, pp. 7-10 NPTEL https://nptel.ac.in/courses/108/102/108102121/
5. Shruti, Speed Control of BLDC using Fuzzy Logic, International Journal of Innovative Research in Science, Engineering and Technology(An ISO 3297: 2007 Certified Organization)Vol. 5, Special Issue 9, May 2016
6. Padmaraja Yedamale, "Brushless DC (BLDC)Motor Fundamentals", Microchip Technology Inc.,
7. Feng Yaojing, Yang Kai, Huang Shoudao, Gao Lei, Zhang Wenjuan, "Research of Interior Permanent Magnet Brushless DC Motor for Electric Vehicles", 2013 International Conference on Electrical Machines and Systems, Oct. 26-29, 2013, Busan, Korea
8. Hanif F. Prasetyo, Arief S. Rohman, Farkhad I. Hariadi, Hilwadi Hindersah, "Controls of BLDC Motors in Electric Vehicle Testing Simulator" 2016 IEEE 6th International Conference on System Engineering and Technology (ICSET) October 3-4, 2016
9. Juhi Nishat Ansari, Sapna L, "Speed Control of BLDC motor for Electric Vehicle",International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 3 Issue 5, May – 2014