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Research Article

Optimizing Torque Ripples In Switched Reluctance Motor Via ANN

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ARTICLE INFO

ABSTRACT

This paper provides a detailed analysis of the performance of SRM motors, focusing on reducing high ripples. In this modern world, there are various types of motors available, among them SRM is getting recognition cause of its inherent advantages such as simple construction, high speed, low cost, high efficiency, and reduced dependency on rare-earth materials and offering significant advantages of both IM and DC brush motors. These traits position SRM as a superior choice among variable-speed motors. But its performance is affected by high ripples and noise. To address this issue, the research inspects the application of Artificial Neural Networks (ANNs) to attenuate torque ripples in SRMs and build up their overall performance. Artificial neural networks are found to be a favourable technique because of their accurate results, simplicity, speed, and stability compared to other methods like PI and HCC, which are undesirable in transient responses. A comprehensive study was performed using MATLAB SIMULINK to demonstrate the positive outcomes, including the presented waveforms

Keywords: Switched Reluctance Motor (SRM), Artificial Neural Network (ANN), Optimization & Modelling, Torque Ripple, Speed Control.

Introduction

The first electrical machine based on the concept of switched reluctance was invented in 1838, and this machine is known as the switched reluctance machine (SRM), which is a monument to the development of electrical equipment. However, real progress in this field of study did not occur until the semiconductor revolution. Prior to 1965, the use of SRM in applications was restricted because of complicated control specifications and technological limitations.[1] The typical approach to modelling and evaluating business processes is now workflow nets, or WF-nets. They provide a flexible framework that may be used to represent different concurrent systems, including web services, going beyond standard workflow modelling. A key characteristic of WF-nets is soundness, which guarantees that every job has a chance to be executed and keeps the modelled system free of redundant data, deadlocks, and live locks.[2] The continuous investigation and development of different alternatives to conventional systems is a result of the search for motor technologies that are effective, dependable, and affordable. Although induction motors (IMs) and permanent-magnet motors (PMs) have been the first choices, they are not without drawbacks. [3] The design and implementation of a neural network-based switched resistance machine controller are the main topics of this research. The particular SRM taken into account in this study is an 8/6, 4-phase SRM, and the converter type selected is an asymmetric converter.[4,14] One of the first electrical machine inventions, switched reluctance machines (SRMs) are widely sought-after for both home and commercial uses, including the aerospace and automobile sectors, due to their straightforward and durable design.[5] In addition, we illustrate how BBDDs may be used to synthesize and verify circuits in new technologies, demonstrating how well these sophisticated systems can handle the particular issues they provide.[6] Although switched reluctance motors (SRMs) have been around for more than 150 years, the development of changeable speed drives with SRMs has been aided by notable developments in power electronics drive technology.[7] Nevertheless, they do have certain disadvantages, such as acoustic noise and torque ripple. If certain techniques for reducing ripple are not used, high torque ripple is a prevalent problem in SR motors.[8], which may provide power in the range of several hundred kilowatts to fractional horsepower.[9] Using online data to estimate the flux-linkage characteristic of the SRM is a superior method. Alternative techniques employ intricate co-energy computations to indirectly calculate electromagnetic torque. These approaches integrate flux-linkage properties at various rotor locations and up to the necessary current level.[10] Reducing vibration and audible noise, optimizing torque per ampere, and limiting torque ripple at low speeds are some of the main goals of SRM control. Reaching these goals frequently calls for precise torque measurement, which is typically made possible by pricy external torque transducers.[11,18] The development of intelligent controller systems, such as fuzzy inference systems (FIS), artificial neural networks (ANN), and robust controllers, has been investigated in the literature as a means of addressing SRM control. These systems aim to modulate the current waveform in electrical drives in order to achieve speed control and minimize torque ripple.[12] Since the first mathematical model of the neuron was conceived in 1943, Artificial Neural Networks (ANNs) have had a long and illustrious history. Scientists have continued to be interested in challenges linked to ANNs over the years.[13] Torque ripple presents a problem for the development of high-performance controllers, especially during phase commutation. It is greatly impacted by the electromagnetic properties of the machine.[15] A number of methods have been put out in the literature to reduce torque ripple in SRMs. Among these is the application of torque sharing functions (TSFs), which reduce torque ripple by indirectly profiling currents.[16] The paper's next parts go into further detail on the case studies, numerical data, issue formulation, system model, and solution technique. Concluding thoughts and suggestions for more research are finally covered.[19] Switched reluctance motors, or SRMs, are widely used in industrial applications because of their fault tolerance, high torque density, resilience, low cost, and efficiency across a wide speed range.[20] The purpose of this study is to build a 2-phase 4/3 SRM especially for blender applications, therefore overcoming some of the inherent problems of SRMs.[21] By using an integrated strategy, the article hopes to further the development and broader use of SRMs in a range of automotive and industrial applications.[22] Power electronic converters are an appealing option for the future of electric propulsion because of their integration, which further improves their controllability.[23] Research indicates that, especially in variable-speed drive applications, SRMs can provide up to 20% cost savings and 4% greater efficiency when compared to induction motors.[24] In conclusion, even though SRMs have many benefits, such as fault tolerance and a straightforward design, resolving torque ripple is still a major obstacle to their wider use.[17] A thorough understanding of the many contributing elements, such as dc-link voltage, load current, phase voltage, inductance, rotor position, and speed, is necessary for the design of an ideal output power management system for SRGs.[25]

II PROPOSED SCHEME:

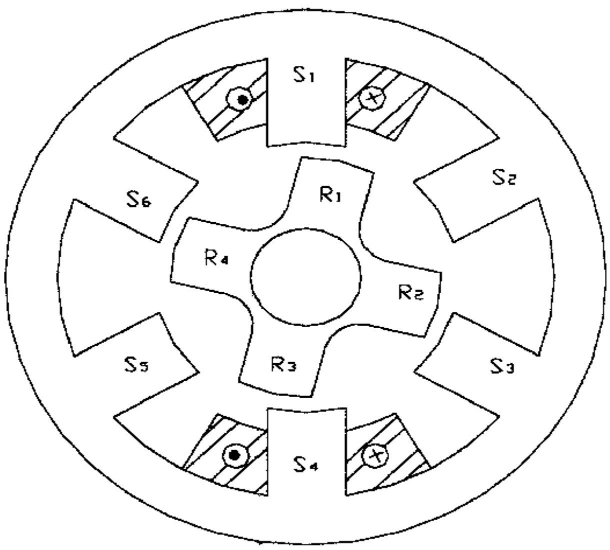


Fig-1: 6/4 Pole Switched Reluctance Motor

6/4 pole SRM is shown in Fig-1. The phases of the stator winding are managed by eight freewheeling diodes that run at 900 volts per phase and eight power electronic IGBT switches.

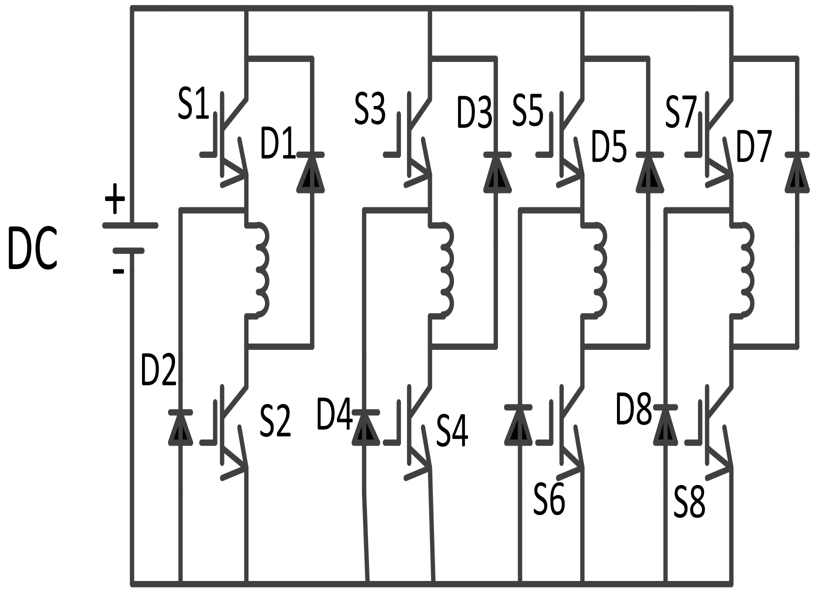
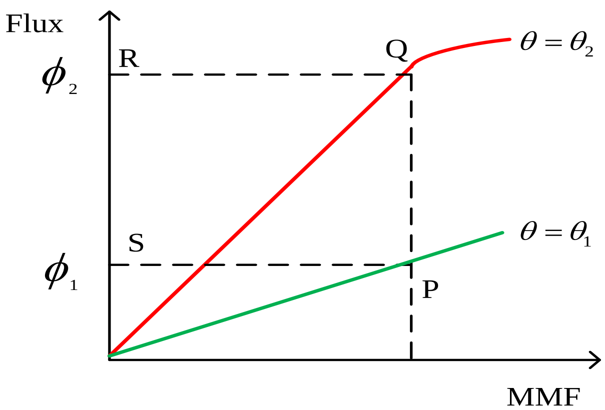


Fig-2: SRM Power Converter Circuit

Fig-2 displays the SRM power converter circuit. The fast speed and lower cost of the three-phase, six-four-pole SR motor are its benefits. Increased torque ripples are one of this motor's drawbacks. In this research, An SR motor was constructed in order to solve the torque ripple issue. This motor uses more power electronics switching devices, has a reduced torque ripple, and has greater beginning torque, but it also has advanced missioned costs and converting losses.



The input energy W is provided as follows when the phase winding is stimulated:

$$w = \int VIdt \quad \text{(I)}$$

A voltage produces an electromotive force (EMF).

$$V = \frac{D(N\phi)}{Dt} \quad \text{(II)}$$

So, one way to describe the energy input would be

$$w = \int F_i d\phi \quad \text{(III)}$$

Fi = N i is the phase winding's MMF excitation. The mechanical energy is transformed into motion in the output.

$$w = w_f + w_o \quad \text{(IV)}$$

Small changes can be made by reframing the above equation.

$$\delta w_i = \delta w_f + \delta w_o \quad \text{(V)}$$

One may compute the corresponding energy for the specified current and MMF as

$$\delta w_i = \int_{\varnothing_2}^{\varnothing_1} F_i d\phi = Area(PQRS) \quad \text{(VI)}$$

$$\delta w_f = area(OQR) - area(OPS) \quad \text{(VII)}$$

Therefore, additional manufacture get-up-and-go equals

$$\delta w_o = \delta w_i - \delta w_f = area(OPQ) \quad \text{(VIII)}$$

This is the space for a certain MMF between its two attributes. The progressive rise in output power in response to a shift in rotor position is one approach to describe electromagnetic torque.

$$T = \frac{\delta w_o}{\delta \theta} \quad \text{(IX)}$$

This incremental output energy is mapped to the energy difference between the aligned and unaligned locations and is represented as the intensity complement of the attractive field:

$$w_f^{'} = \int \phi dF_i = \int N\phi di = \int L(\theta, i) i di \quad \text{(X)}$$

The inductance, L, is a function of rotor position and current and is represented by the flux linkage over current.

$$t = \frac{\delta w_f^{'}(0, I)}{\delta \theta} \quad \text{(XI)}$$

For a given current, the inductance changes linearly with rotor position in the absence of magnetic saturation, producing a torque of

$$t = \frac{1}{2} i^2 \frac{dL(\theta)}{d\theta} \quad \text{(XII)}$$

Once magnetic saturation is reached, the torque cannot be written as an easy algebraic equation and must instead be stated as an integral:

$$t = \int_0^i \frac{\partial L(\theta, I)}{\partial \theta} \quad \text{(XIII)}$$

The stator flux :

$$\vec{\lambda} = \int \left(\vec{v}_s - R_s \vec{i}_s \right) Dt \quad \text{(XIV)}$$

The flux of the rotor in the SR motor may be written as

$$\vec{\lambda} = L_r \frac{\vec{\lambda}_s - L_s \vec{i}_s}{L_m} + L_m \vec{i}_s = \frac{L_r}{L_m} (\vec{\lambda}_s - \sigma L_s \vec{i}_s) \quad \text{(XV)}$$

Where σ , which can be represented as the total flux leakage factor

$$\sigma = 1 - \frac{L_m^2}{L_s L_r} \quad \text{(XVI)}$$

Divide the flux of rotor into its components along the axes, and we get

$$\vec{\lambda}_{dr} = \frac{L_r}{L_m} (\vec{\lambda}_{ds} - \sigma L_s \vec{i}_{ds})$$

$$\vec{\lambda}_{qr} = \frac{L_r}{L_m} (\vec{\lambda}_{qs} - \sigma L_s \vec{i}_{qs}) \quad \text{(XVII)}$$

The angle and magnitude of the rotor flux are

$$\lambda = \sqrt{\lambda_{dr}^2 + \lambda_{qr}^2}$$

$$\theta_f = \tan^{-1} \frac{\lambda_{qr}}{\lambda_{dr}} \quad \text{(XVIII)}$$

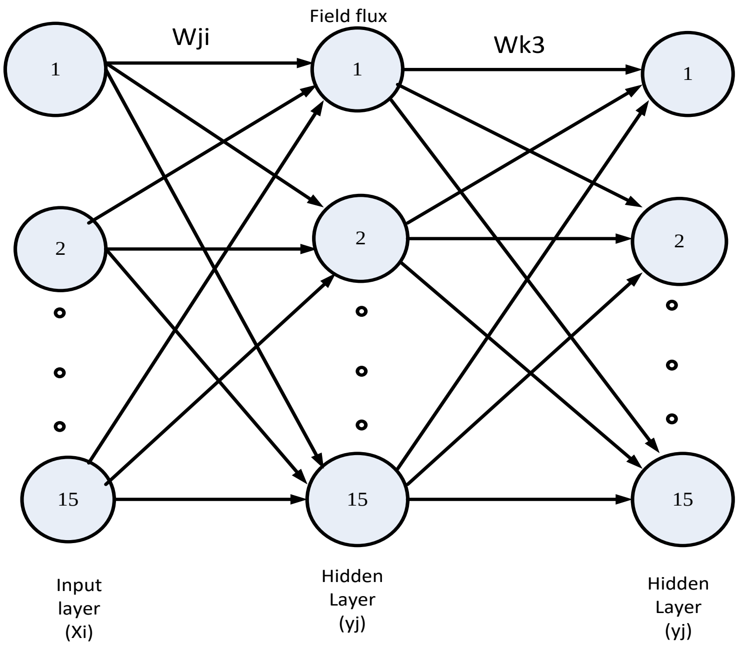


Fig-3: Architecture of ANN circuit

Two hidden layers and an output layer, and four layers of input make up an ANN circuit. Speed is the input layer, torque is the output layer, and speed to torque converters are hidden layers.

III PROPOSED METHOD:

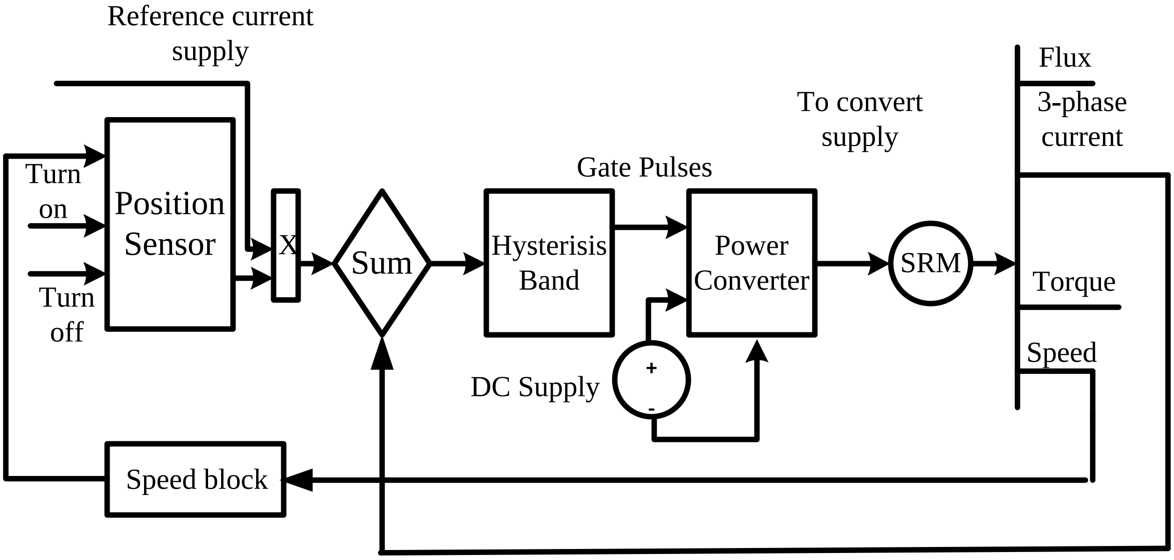


Fig-4: SRM Hysteresis Control Circuit

Fig-4 demonstrates the six blocks that make up the SRM control scheme: the position sensor, speed block, HCC, reluctance motor, power switching circuits, and Add. By comparing the reference current and real current, the sum block produces an erroneous current signal. The SRM stator phases of the power converter circuit controllers.

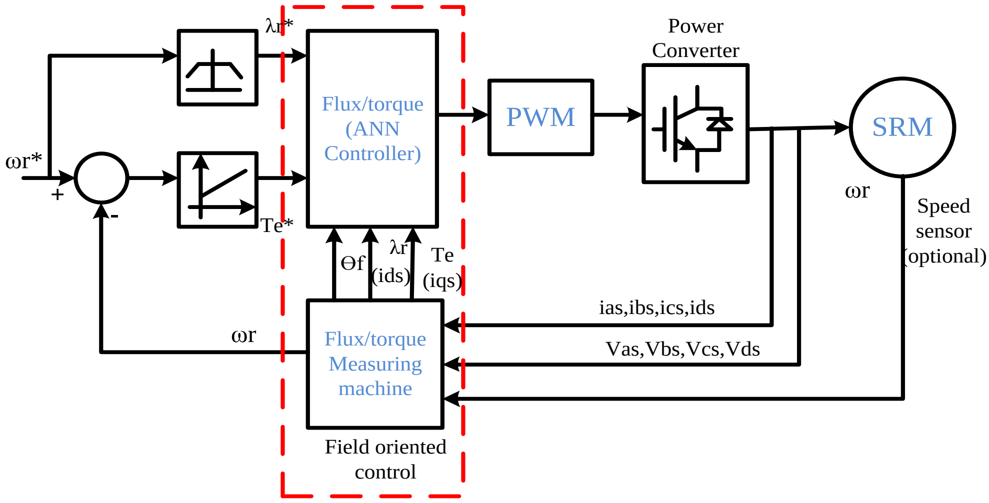


Fig-5: SRM ANN Control Circuit

Fig-5 displays an ANN controller for SRM. Toque, flux converter, and speed comparator blocks. An 6/4 pole makes up the SR motor. The power converter block receives PWM pulses from the ANN controller and regulates the phases of the stator. It requires the flux/torque estimator block reference signals created flux, toques, speed, phase angle, and current, voltages, and speed.

IV SIMULATION RESULTS:

A . Reluctance motor with HCC

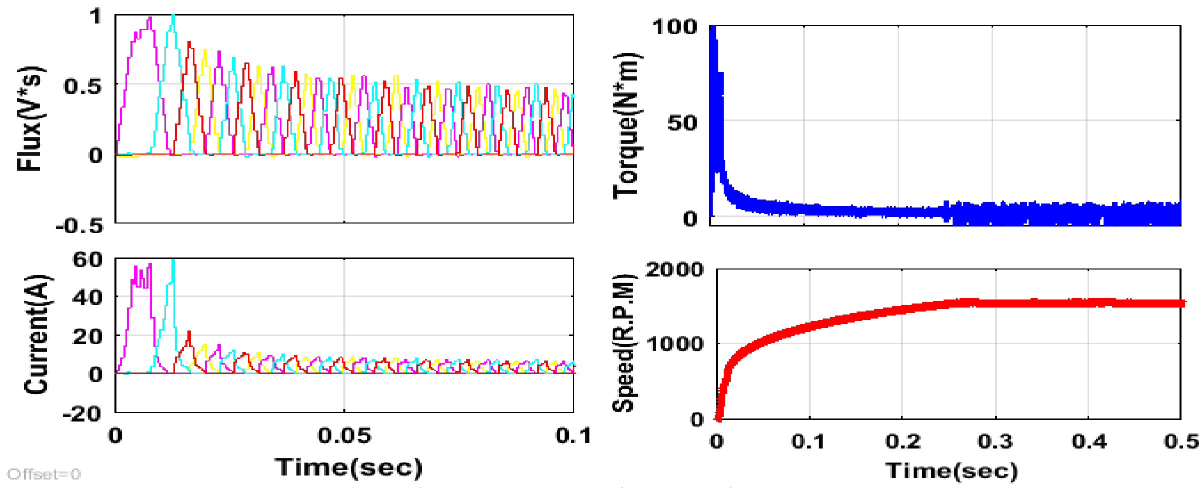


Fig-6: SRM Waveforms with HCC

Fig-6 displaying the SRM simulation model with hysteresis current controller in MATLAB. An 8-pole and 4-phase SR motor is shown in this circuit. A Switching circuits regulates the motor-powered. Each power converter controls a distinct phase of the SR motor. The Switching circuits is equipped with two freewheeling diodes and two IGBT switches. Figure shows the flux, torque, current and speed waveforms of the SR Motor using the HCC. As shown in the waveforms of the simulated outcomes, the starting flux is twice as large as the flux under operating conditions. After 0.03 seconds, the flow achieved steady-state conditions. The SRM draws 60 A of electricity when it is first turned on and 15 A when things are stable. In the initial state, the torque is ten times greater. After 0.25 seconds, the SRM speed enters a constant state.

B . SRM with ANN Controller

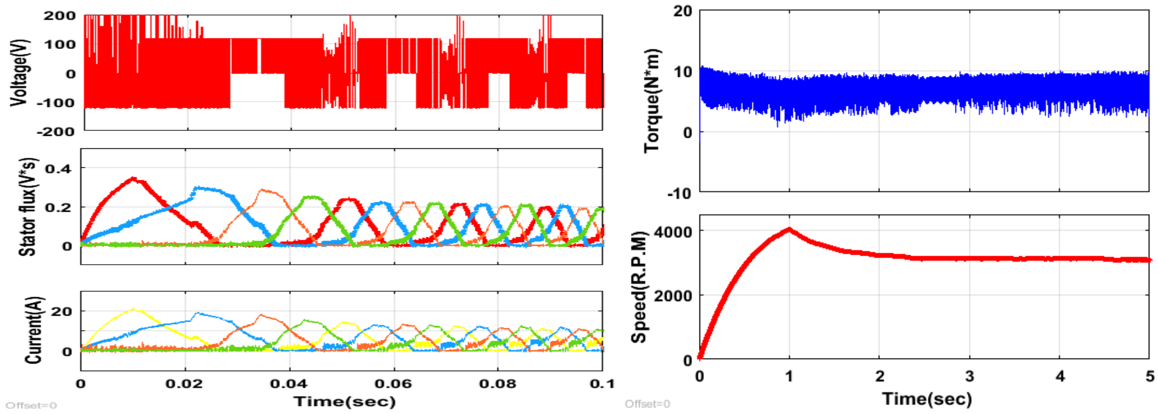


Fig-7: SRM Waveforms with ANN Controller

Fig-7 displays the SRM's voltage, torque, stator flux, current and speed waveforms using ANN. In the flux waveform of the simulated outcomes, the early flux is twice as large as the running condition flux. Starting at 20A, the SRM draws 11A of current when operating in a constant state. In 0.04 seconds, the flow reached steady-state conditions. In both running and starting conditions, the torque is the same. After one second, the Reluctance motor rapidity achieves a constant state.

C . HCC and Artificial neural networks Contrast Results

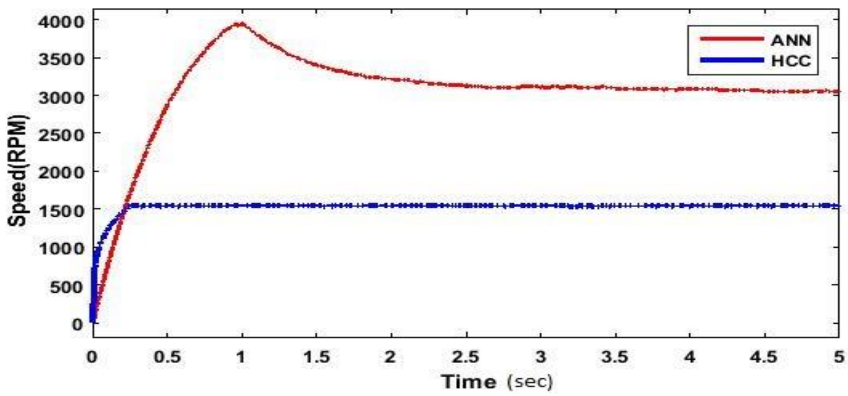


Fig-8: SRM Speed Comparison between HCC & ANN

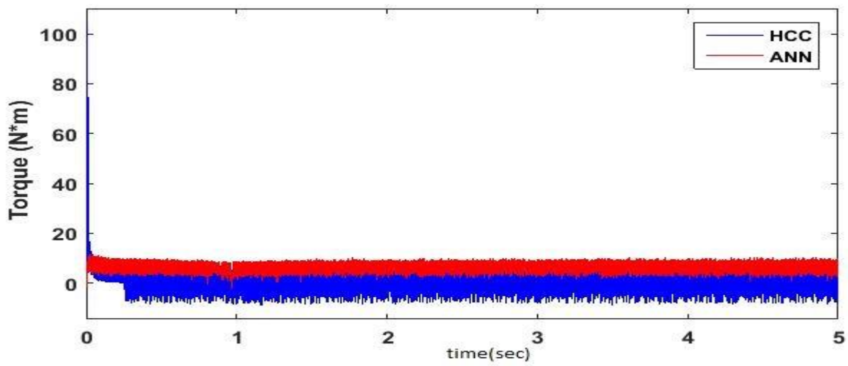


Fig-9: SRM Torque Comparison between HCC & ANN

Fig-8 & Fig-9 Findings from the comparison of the speed HCC/ANN controllers. The Artificial neural network controller performed faster and with more efficiency. The motor under HCC control ran at 1500 RPM, whereas the motors under ANN control ran at 3000 RPM. A unchanging rapidity of 0.2 seconds is obtained by the HCC-controlled motor and 1 second by the ANN-controlled motor. In the beginning situation, the rated torque is eight times lower than the HCC controller torque. The starting torque of the ANN-based controller is the same as the amounted twisting force.

V CONCLUSION:

ANN-based SRM is provided in this study. MATLAB/Simulink program simulates a motor. The speed, torque, stator current, and flux obtained from the simulation are confirmed. This research uses field orient control (FOC) to estimate direction angle, flux, torque, and speed. Results of ANN-based simulation were confirmed using the HCC controller. When compared to HCC, the ANN-based SRM performed better. An ANN-based controller decreased running and starting current, enhanced speed, and lessened torque ripples.

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