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Speed Estimation of an Asynchronous Motor with Feed Forward Neural Network

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Abstract: AC asynchronous motors are the most frequent motors used in industrial motion control systems as well as in main-powered domestic appliances. AC asynchronous motors provide several advantages, including a simple and durable construction, low cost, low maintenance, and direct connection to an AC power source. On the market, there are many different types of AC asynchronous motors. Diverse motors are suitable for various applications. Like other motors, an AC asynchronous motor contains a stator that is fixed on the outside and a rotor that spins within, separated by a precisely designed air gap. Almost all electric motors use magnetic field rotation to spin their rotors. Asynchronous motors are the most commonly utilized electromechanical machinery in industrial applications. There have been several research on their control, as well as a variety of approaches for achieving high-performance speed drivers. The properties of asynchronous motors alter with time and under different operating situations. Even though much research has gone into developing artificial neural network techniques to estimate the speed of an asynchronous motor and some of the parameters such as flux and torque, there hasn't been much work done on asynchronous motor speed estimation using artificial neural networks.

The main purpose of this paper is to build a speed estimator for an asynchronous motor using a feed-forward artificial neural network. A mathematical model for the asynchronous motor is developed and implemented in Matlab. A speed estimator is then developed using a feed-forward neural network and coupled to the asynchronous motor to estimate its speed. After that, simulations are done to see how well the proposed speed estimator performed.

Keywords: Space Vector Modulation PWM (SVPWM), Artificial Neural Networks (ANN), magnet Permanent magnet Synchronous Motor (PMSM)

I. INTRODUCTION

An AC induction motor, like other motors, contains an additional exterior permanent part called an inner stator and a rotor that rotates with a properly built air gap. Almost all electric motors use magnetic field rotation to rotate their rotors. The 3-phase motor for AC induction is the only kind in which the magnetic field rotates spontaneously in the stator due to the supply arrangement. DC motors rely on rotating magnetic fields, which can be switched mechanically or electrically.[1] A single-phase AC induction motor requires additional electrical components to generate this spinning magnetic field. Two sets of electromagnets are formed inside each motor. The AC supply connected to an AC induction motor's stator windings is utilized to create a series of electromagnets. According to the law of Lenz, an alternate power source voltage (EMF) is induced on the rotor (much like the voltage produced in the secondary transformer). The magnetic fields of such electro-magnets interact, causing twisting or torque. The motor spins in the torque direction as a result of this. Induction Motor Speed, the stator magnet field revolves synchronously at speed (NS) where:

NS = the Stator Speed Synchronous magnetic field in RPM
P = The pole number on the stator
f = the supply frequency in Hertz

Due to the induced voltage, the magnetic field formed in the rotor alternates in nature. To maximize the relative speed, the rotor begins to travel in the same direction as the stator flux and tries to keep up with the spinning flux. However, the rotor is unable to "catch" the stator's field.

The stator's field follows.[2] The rotor has a lower field speed than the stator. This is referred to as the base speed (Nb). The slip is the name for the NS-NB gap. The amount of slides is determined by the load. A load increase might cause rotor slip to be delayed or increased. A rotor's slip will be sped up or reduced as the load is reduced.

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II. ARTIFICIAL NEURAL NETWORKS (ANN)

A taxonomy of ANN schemes and how ANNs are trained based on their learning. The classification is based on a method of information data management in which they are given the unknown input X. The goal is to identify the weight distribution in the vicinity of a fresh X observation. Figure 1 depicts the basic network concept. They can have different architectures and are built up of numerous layers of neuronal organization. Even the preparation should be supervised or supervised by you.[3]

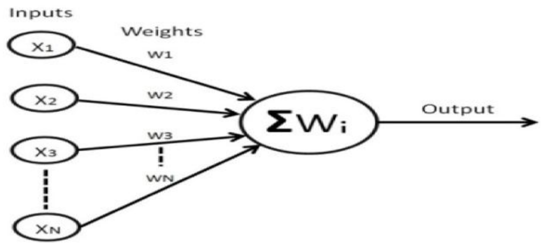

Fig.1Speed Estimation using ANN

The capacity of ANNs to approximate nonlinear functions is the reason for their appeal. They're frequently utilized to address problems that are classified as black-box. The design technique presupposes that we are familiar with input and output signals, but not with the mathematical description of the process taking place inside the black box. Many attempts have been made to tackle various estimate challenges that occur in black-box drives.[4] When it comes to mechanical speed, using ANN as a function f1 approximation, which is defined as follows, is a fairly simple choice.

$$\omega_r^{(k)} = f_1\left(u_{-s}^{(k)}, i_{-s}^{(k)}, u_{-s}^{(k-1)}, i_{f_1}^{(k-1)}, \mathrm{K}\right)$$

To be practical, the length of the tapped delay lines (TDLs) and the number of delayed signals must be limited. A single delayed signal, for example, was hypothesized and partially proven to be sufficient. This relationship can be function-like even for zero-length TDL in some AC motor control systems.

A. Perceptron Model for ANN

NNs have different ideas about what they are. To begin, the sensor is the most basic. It can tell if an input belongs to one of two categories and has two different activation functions (AFs). A hard limiter, a logic threshold (ramp), a linear one (sigmoid), and (the most common) a logistic characteristic of Sigmoidal are commonly included in its list of AFs. The mathematical model is as follows:

$$y = \phi\left(\sum_{i=1}^{N} w_i x_i - b\right) \qquad X_1, X_2, \mathrm{K}\, X_N$$

Inputs are provided by device signals, the appropriate weights, b is the neuronal bias, and is the AF. Figure below

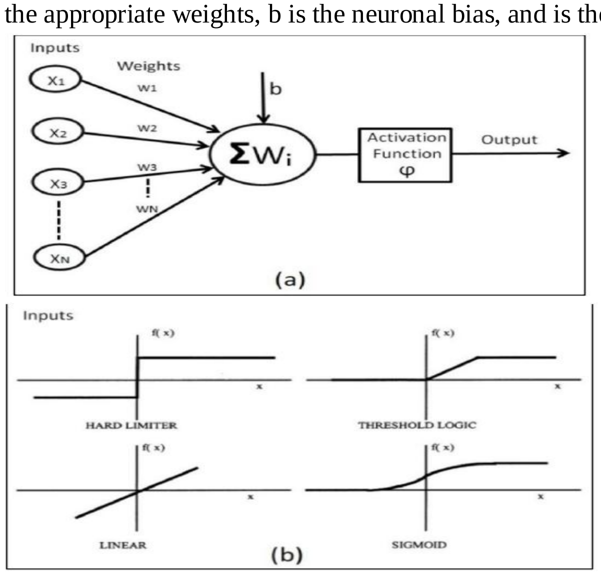

Fig.2 A perceptron and its activation functions, (a) and (b) respectively

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III. RESEARCH METHODOLOGY

A mathematical model for an asynchronous motor has been devised and implemented in Matlab. Then, using a feed-forward neural network, a speed estimator is- created and coupled to the asynchronous motor to estimate its speed. After that, simulations anticipate the suggested efficiency speed estimation run.[5]

A. Speed Estimation using Neural Network

For predicted induction motor pace difficulties, there are numerous model-based solutions. Their effectiveness is largely determined by the accuracy with which parameters are identified. Open-loop observers (calculators) and closed-loop observers are the two main types of observers. Due to the inclusion of a correction loop, the former are usually quite sensitive to parameter fluctuations, whilst the latter is more resistant. They can also be categorized based on the methods utilized during the design process. With ANN as an adaptive model, there is a class of MRAS-like estimators. ANN training techniques are used to derive an adaptability rule (e.g. error backpropagation method).[6] L.Ben- Brahim and R. Kurosawa are undoubtedly the most well-known and frequently mentioned. The adaptive model is built in the form of a linear neuron The calculated speed is proportional to one of the weights.

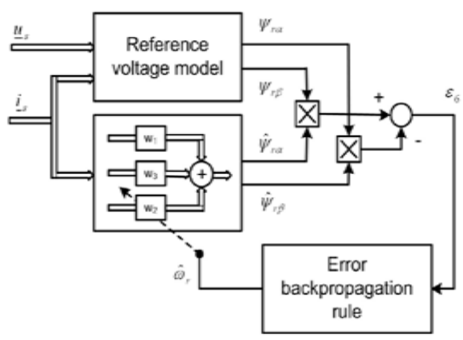

Fig. 3 . ADALINE-based MRAS speed estimator

IV. RESULTS

In general, ANNs are utilized to solve a wide range of black-box estimate issues. Only the input and output signals are known in black-box estimation issues and their mathematical relationship is unknown. Real-world estimate problems, on the other hand, are typically Gray-box estimation problems, which may be characterized using some type of mathematical description. Because an asynchronous motor's rotor speed does not have a unique function and incorporates numerator and denominator functions, ANN cannot be used to estimate its speed directly. So far, we've created six-speed signals by changing voltages and currents in the job at hand. The entire framework and Simulink software are implemented in MATLAB. For speed estimate, a feed-forward ANN was utilized.[7]

The Simulink model's block diagram is shown in Figure4.

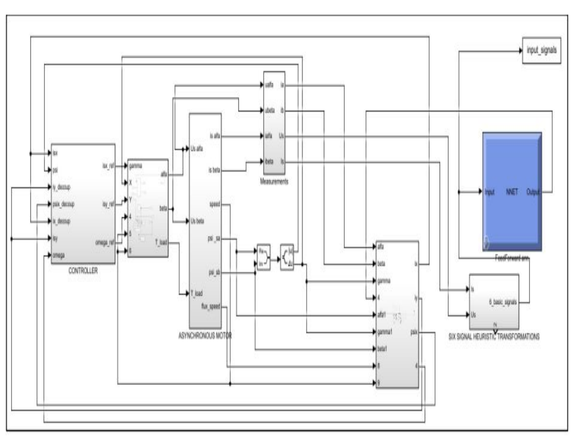

Figure 4. Block Diagram of Model Implemented in Simulink

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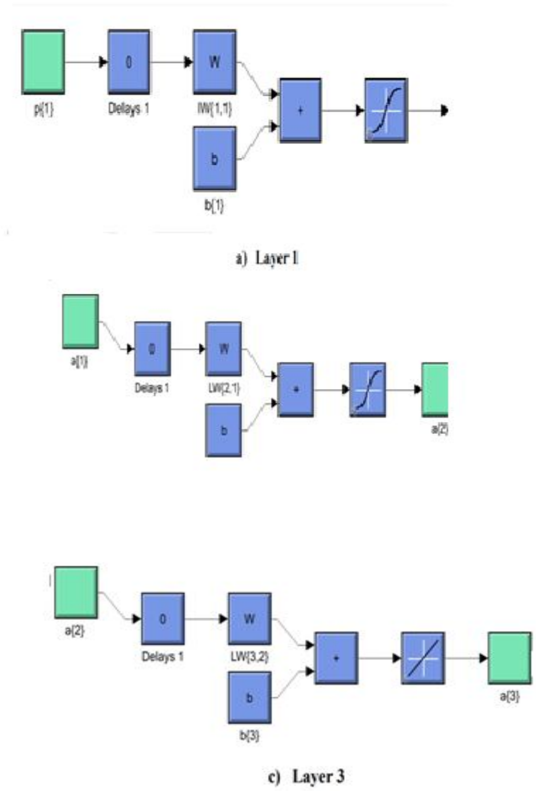

Fig.5 The feedforward Network of neural nets is made up of 3 layers. Layers 1 and 2 use the Sigmoid function and Layer 3 uses the linear function

V. CONCLUSION & FUTURE SCOPE

Asynchronous motors are widely employed in power and a variety of industrial applications. The characteristics of an asynchronous motor change with time and under different operating conditions. Despite extensive research, the speed of an asynchronous motor has been determined. Although ANN has been used to predict some parameters such as flux and torque, little work has been done on the speed estimation of asynchronous motors. In this paper,[8] the usage of a feed-forward ANN to approximate the speed of an asynchronous motor was investigated. As previously discussed, ANNs are well-known for their use in the estimation of nonlinear equations. The use of artificial neural networks (ANN) to tackle a wide range of black-box estimate issues is prevalent.

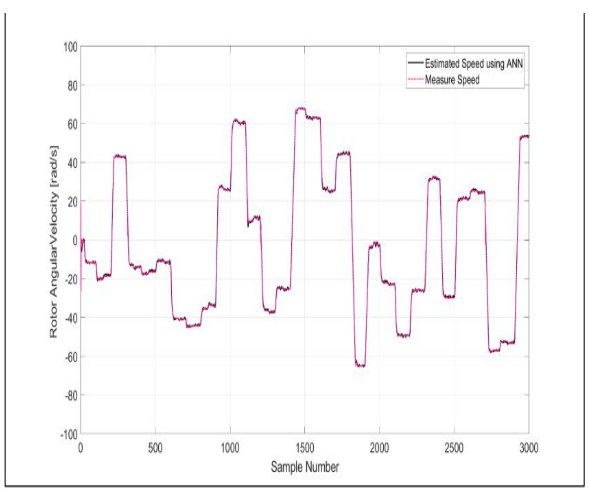

Fig.6 Measured and Expected Speed of Asynchronous Motor

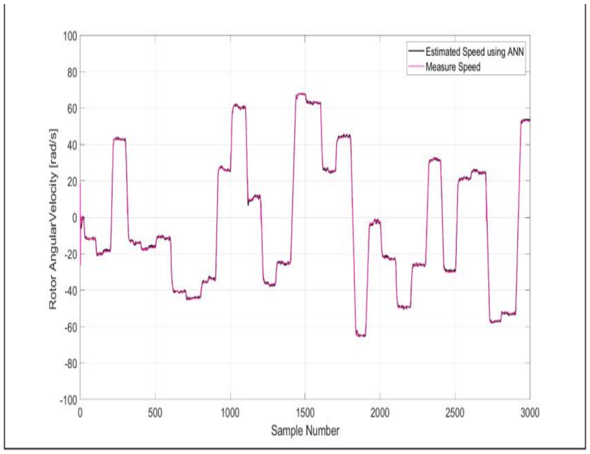

Fig.7 Variation of Torque of Asynchronous Motor

Only the input and output signals, as well as their mathematical relationship, are known in black-box estimation problems.
Real-world estimate problems, on the other hand, are typically Gray-box estimation problems, which may be characterized using some type of mathematical description.[9] Because an asynchronous motor's rotor speed does not have a unique function and incorporates numerator and denominator functions, ANN cannot be used to estimate its speed directly. The feedforward ANN was employed in this study. However, in the future, backpropagation ANN or a deep neural network can be used to estimate motor properties.

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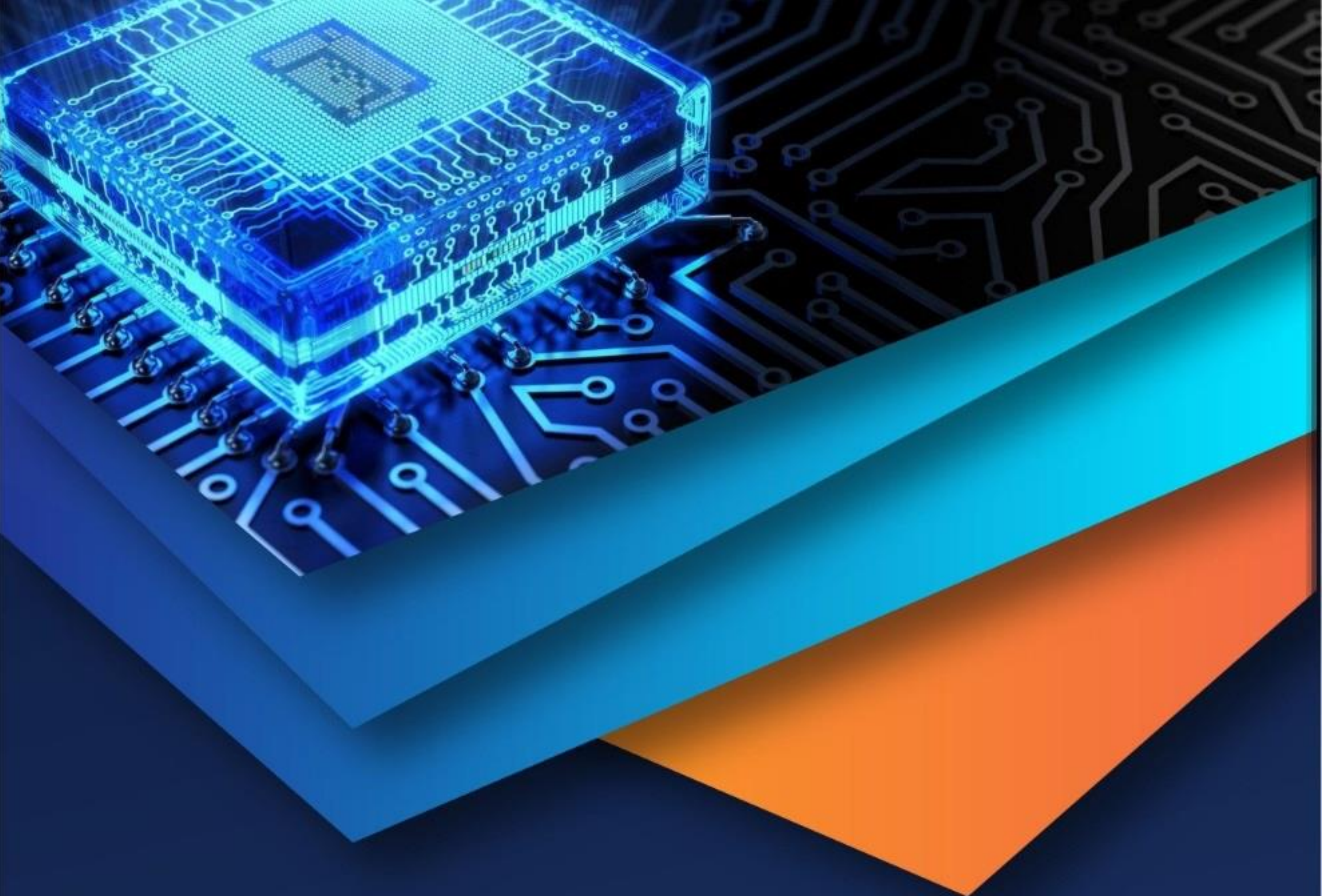

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