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A Review of Soft Computing Approach for the Speed Estimation of Electric Drive

Sameer

Shah Satnam Ji P.G Boys College, Sirsa, India

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Abstract

This paper describes a novel method of speed estimation in the field of automation and control of electrical drives based on artificial intelligence (AI). The artificial neural network (ANNs) models are composed of many non-linear computational elements operating in parallel and arranged in patterns similar to biological neural nets. This paper details a proposed scheme to identify the use of neural network model for the estimation of the speed of the rotating shaft driven by voltage controlled induction motor drive. In most of the process control applications the speed identification is based on the conventional analog type of electro-mechanical sensors like tachometer, optical pyrometer etc. These sensors require dynamics of the plant being controlled and are at risk of life due to the high-speed continuous motion of the shaft. Moreover, the conventional adaptive control schemes are complicated and need excessive computational effort for real time implementation. The paper proposes the highly parallel building blocks that illustrate neural net components and design principles used to track the systems like-speed estimation of induction motor drive. It details about the preferable use of contact less type of ANN model based sensors over the conventional one. The verification of the proposed work through physical experimentation definitely suggests the use of neural networks to solve the above problems by mimicking the adaptive control architecture in human brain.

Keywords: *Artificial Neural Network (ANN), Estimator, Back-propagation algorithm, Induction motor, Adaptive control.*

1. Introduction

Electric drives offer a convenient means for controlling the operation of different devices used in industry. In the proposed work it is intended to estimate the rotating speed of the shaft driven by an induction motor under variable voltage controlled mode by means of neural network [1]. At the preliminary stage the work involves the simulation of multi-layer neural network model as described above on the digital computer with the use of suitable software tool. The simulation process based on the particular training algorithm involves the training and testing of the network with the various patterns of input / output real time data. The processing of real time data to the simulated network is done through PC as a host computer.

The host computer contains all the mathematical functions and relations and proposes a simulated model or design for the neural network. Various input patterns are given to it and the corresponding output patterns are verified. The verification of output patterns is based on the computation of error measured with desired output patterns. The mappings of certain input and output data pattern are realized for numbers of iterations till the computational error converges to minimum acceptable level. The numbers of simulated neurons in the hidden layer are changed in view of the modification of weight matrix for an efficient training of the network. Thus, based on the performance of the simulated model only final architecture of the network is designed. The Matlab based neural network software toolbox in conjunction with 'Simulink' block set is used for the simulation of a neural network model on a digital computer. The minimum necessary hardware infrastructure essential to carry out the required training process is comprise of an induction motor of suitable horse power rating (5 HP), PC as a host computer with real time data software tool box, conventional analog type of sensor element, voltage/current sensing elements, hardware interface in the form of electronic comparator, A/D and D/A converter.

2. Back propagation training algorithm

The Back-propagation (BP) training algorithm [1] is used for supervised training of a layered neural network model. The network is trained for desired input/output data relationships in of view of the correct estimation of the speed of the voltage controlled A. C. induction motor driven under variable load condition [1, 2]. The input layer is consists of two input nodes. The first input node receives the input voltage signal as a variable operating voltage applied across the stator windings. The second input node receives the current input signal representing the current dragged by motor under variable load condition. The output layer is comprise of one output node to provide the output signal representing the estimated rotating speed of the shaft driven by an induction motor. The number of hidden layers and number of simulated neurons under each hidden layered are varied to access improvement and/or degraded performance of the model.

3. Hardware implementation of neural network training algorithm

The squirrel cage induction motor is simple, reliable and economical in operation. It provides excellent characteristics at a constant shaft speed. The measurement of the operating speed of the rotating shaft driven by motor is done by means of an appropriate speed sensor. An introduction of ANN simulated model as a speed estimator eliminates the need for contact type of sensor for speed control schemes developed for variable voltage and frequency induction motor drives. Such schemes make use of either model reference adaptive control or neural networks.

The scheme presented here is based on input- output relations obtained experimentally and does not involve machine equations. The error due to parameter variations does not arise and so improved accuracy is achieved. A multi-layer back-propagation neural network is trained off-line to learn the dynamics of the system with no priori knowledge. The ANN is trained with adaptive learning and momentum rule. The function approximation capability of a feed forward ANN is used for motor speed identification. The scheme for training the network is shown in Fig. 1.

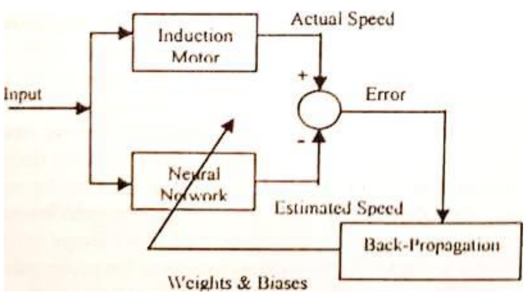

Figure 1. Training of Neural Network as a Speed Estimator

The details of three-phase induction motor are:

415V, 7.1 Amps, 1440 rpm, 5 II. P. and 50 Hz. The input is applied to the motor under test and to neural network. The prerequisite optimal data required for an estimation of the slip of induction motor is in terms of applied voltage and current fetched by its stator windings from the mains [1,2].

The real time processing of these input signals probably done through data acquisition board consists of A/D converter, scaling and normalization circuits with PC as a host computer [3]. The output signal at the output node indicates the operating speed for various input patterns.

The D/A signal conditioning of output signal measures the estimation of the speed by a neural network, which is continuously compared against the analog output signal from the conventional speed sensor. The electronic comparator circuit in the form of a basic building block of operational amplifier operating in a differential amplifier mode compares the actual measurement of speed determined by the conventional sensor and the estimation of the speed determined by the neural network. The output of the electronic comparator provides the error signal, which is feedback to the network. This error signal is back propagated from an output to input layer for numbers of iterations based on the earlier proposed back-propagation training algorithm, till the mean square error (MSE) computed at the output node converges to a value within a specified acceptable tolerance band limits.The supervised training based on back propagation training algorithm of simulated neural network model is done with the several combinations of repeated input/output patterns till the time when network is fully trained to give the correct estimation of the speed. The testing of the network is done by means of application of another set of desired input/output patterns. With successful testing of the neural network as speed estimator, the conventional analog type of speed sensor mounted on to the rotating shaft of the motor is conveniently eliminated so as to enhance the reliability and robustness of the drive system. The physical experimentation of this proposed work use of such speed sensor.

Conclusions

The paper details the suggested approach for tlie identification of the speed with the use of neural network. It describes the methodology of the work oriented towards tlie hardware implementation for the training of neural network model as a speed estimator.

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