

Harmonics Reduction in Supply Source Using ANN for Induction Motor

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ABSTRACT

Power system engineers are deeply concerned about the negative effects of harmonics caused by nonlinear loads on the quality of power. Recent research has focused on addressing this issue by employing various filter configurations at the load end. In this study, a new method is presented that utilizes an Artificial Neural Network (ANN) controller to reduce current harmonics at the source end of an induction motor. To enhance the dynamic performance of three-phase induction motors, a vector control approach is employed. A mathematical model of the three-phase induction motor is developed, and both Direct Torque Control based Space Vector Pulse Width Modulation (SVPWM) for a three-phase voltage source inverter and ANN controllers are used to minimize the source current harmonics. The model is simulated using MATLAB/Simulink software and implemented in hardware by integrating an induction motor drive with SVPWM on the supply side. From simulation it is observed that THD is reduced.

Keywords: Artificial neural network, space vector pulse width modulation, vector control, voltage source inverter

INTRODUCTION

Induction motors are widely utilized in both industrial motion control systems and household appliances that run on AC power. These motors widely accepted due to their straightforward and durable design, cost-effectiveness, minimal maintenance requirements and direct connection to AC power sources. The market offers a variety of Induction motors, each suitable for specific applications. Achieving precise control over speed and torque in different types of

Induction motors necessitates a deeper comprehension of their design and characteristics.

The recent surge in high-performance AC drives has garnered significant attention and generated considerable interest in modern industrial and other applications. Researchers are actively engaged in this field, striving to achieve optimal performance for AC variable speed drives (VSDs). Numerous research articles have emphasized the efforts aimed at mitigating

harmonics and improving power factor in AC systems with nonlinear loads. Enhancing power quality in the power system necessitates addressing the challenge of eliminating or reducing harmonics generated by nonlinear loads. The proliferation of nonlinear loads such as rectifiers, inverters, UPS systems, mobile battery chargers, and arc lamps, as well as power electronic converters, has introduced harmonics into the power system. Various types of controllers have been explored to mitigate harmonics using SVPWM technique, each having their own advantages and disadvantages.

The presence of distorted voltage and current waveforms gives rise to several power quality issues, including equipment de-rating, unwanted electrical noise interference, circuit breaker malfunctions, and interference in communication systems, and reduced lifespan, efficiency, and output power of devices.

Harmonic distortion increases the current beyond the rated value which is detrimental to machine/equipment. In this way, to diminish these symphonious mutilations, space vector regulation procedures are utilized. This procedure is utilized in light of the fact that a high level strategy includes calculation serious PWM strategy and conceivably the best method to the variable recurrence drive application.

There are several types modulating technique that controls the amount of time and the sequence that uses to switch on and off. The most used modulating techniques are the carrier-based technique.

For example, the sinusoidal pulse width modulation (SPWM), the space-vector (SV) technique, and the selective-harmonic-elimination (SHE) technique. This paper focus on the implementation of DTC based SVPWM for three phase voltage source inverter.[1,2]

PROPOSED SYSTEM FRAMEWORK ANN Controller

The Artificial Neural Network (ANN) controller has gained significant popularity in diverse engineering and non-engineering applications. In power system applications, ANN is particularly appealing due to its simple structure, ease of training, rapid response, high performance, and adaptability. ANN possesses inherent intelligence, enabling it to make decisions based on well-trained data, biases, and adaptation techniques. Several types of ANN controllers exist, including Backpropagation (BP), ADALINE (Adaptive Linear Element), MADALINE (Many ADALINE), Widrow- Hoff, Perceptron, Radial Base Function (RBF), Hebbian, Competitive Grossberg, and Hopfield.

In the power system domain, ANN controllers are highly regarded for their ability to mitigate harmonics. The proposed prototype system utilizes the ADALINE structure of an ANN controller in the SVPWM technique to facilitate current control. ADALINE's straightforward structure and fast response make it a suitable choice. Fig.1 depicts the ADALINE ANN controller, which consists of an input layer with n-number of inputs, an output layer with two outputs, and a multi-layer feedforward ADALINE

Neural Network. The backpropagation learning algorithm is employed in conjunction with supervised and unsupervised learning. The ADALINE Neural Network adjusts weights based on output error values. The backpropagation supervised learning method is widely utilized in multilayer feedforward ANNs,

making it the approach adopted in this research. The input of ANN controller is the stator voltage and stator currents obtained from the dynamic model of the three phase induction motor. The output variable is the rotor flux and controlled rotor torque.[3]

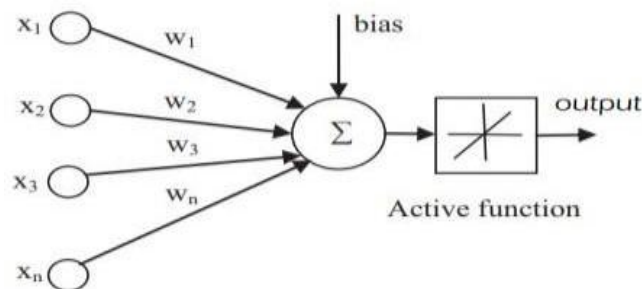


Fig. 1: Schematic of ADALINE network

Space Vector Pulse Width modulation (SVPWM)

SVPWM utilise the available DC bus voltage by 15% more than sine PWM. It will be shown that SVPWM can directly transform the stator voltage vectors from α - β Co- ordinate system to pulse width modulation signals.

A single phase vector (the desired reference vector) is resolved onto α - β co-ordinate and used for generating the PWM signals. Hence there is no error from the input stage. In case of sine PWM, 3 separate sine waves are compared with triangular carrier to generate the PWM signals. If there is an error in the three input sine waves, then the inverter output waveforms will not be balanced. In this case, the SVPWM has become advantageous.

In SV modulation, once the output 3 phase

voltages are known, then a single space vector is calculated in α - β axis. This vector, in α - β axis is applied as a single quantity to the 6 switches of the inverter. Since it is 2 dimension quantity it is easier to derive various formulae to find out the ON period of PWMs for the 3 top switches. This space vector is a compact notation that a single variable contains information about the voltages of all three phase at any given time. The space vector can be better understood if one knows the three phase to two phase transformation. The three phase to two phase conversion methods and derivations of two phase quantities are given below.

Asymmetrical 2-pole, 3-phase winding on the rotor is represented by three coils A, B, C each of N effective turns and mutually displaced by 120° , is shown in the Fig. 2.

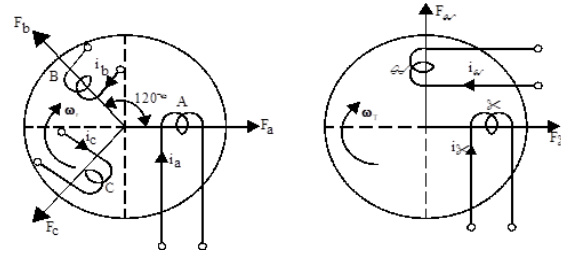


Fig. 2: (a) Original 3-phase (b) Transformed 2 phasesystem.

Maximum values of mmf, F_a , F_b and F_c are shown along their respective phase-axes. The combined effect of these three mmf result in a constant magnitude m.m.f,

which rotates at a constant angular velocity depending on the poles and frequency.

Assuming three-phase currents as

$$\begin{aligned} i_a &= I_m \cos \omega t \\ i_b &= I_m \cos \left(\omega t - \frac{2\pi}{3} \right) \\ i_c &= I_m \cos \left(\omega t - \frac{4\pi}{3} \right) \end{aligned}$$

Then, these will produce an m.m.f of constant magnitude ($3NI_m / 2$) rotating with respect to the three-phase winding at the same time frequency. The space angle between the windings must comply with the time phase angle between the current. A balanced two-phase winding is represented by two orthogonal coils α, β on the rotor. For convenience in transformation, the axes of phase A and " α " are taken to be coincident.

When two phase currents pass through a two-phase winding, it generates a magnetic field of constant magnitude ($I_m N$) that rotates along with the two-phase windings at the same frequency as the phase currents. To ensure that the magnitudes of the magnetic fields in three-phase and two-phase systems are equal, any of the following adjustments can be made.

By changing the magnitude of the two phase currents,

$$\left[V_{2ph} = V_{3ph} \text{ \& } I_{2ph} = \frac{3}{2} I_{3ph} \right]$$

By changing numbers of turns of the two phase windings,

$$\left[V_{2ph} = \frac{\sqrt{3}}{2} V_{3ph} \text{ \& } I_{2ph} = \frac{\sqrt{3}}{2} I_{3ph} \right]$$

By changing both magnitude of currents and number of turns.

$$\left[V_{2ph} = \frac{\sqrt{3}}{2} V_{3ph} \& I_{2ph} = \frac{\sqrt{3}}{2} I_{3ph} \right]$$

In the above-mentioned changes power invariance can be achieved. In the first two types, the voltage and current transformations differ, so the per phase parameters for three phase and two phase systems are not the same. But in the third

type, the voltage and current transformations are similar. So one need to change both the magnitude of currents and the number of turns to derive the space vector.[4]

SIMULATION OF PROPOSED SYSTEM

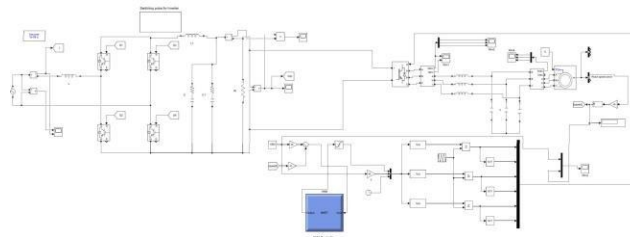


Fig. 3: Proposed system simulation diagram.

The Fig. 3 shows the complete simulation diagram of harmonics reduction in supply source using SVPWM technique ANN controller technology.

Control Block Diagram

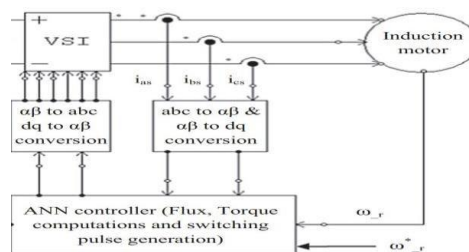


Fig. 4: Control block diagram.

The Fig. 4 shows the control block diagram of 3-phase inverter. The control block diagram consists of several key components that work together to ensure proper operation of the inverter. Here's a breakdown of each component:

Current sensors

These sensors measure the input current of the 3-phase Induction motor. They provide feedback signals to the control system, which is essential for regulating the

inverter's output.

Three-phase to two-phase transformation:
The current sensed from the 3-phase motor input is transformed into two phase d-q system.

ANN controller

The two-phase signal d-q obtained from the above system is analyzed with respect to the rotor speed of the induction motor and a control signal is sent to the voltage source inverter.

Two-phase to three-phase transformation: The control signals obtained from the ANN controller is transformed into three-phase system before fed into the gate signals of voltage source inverter.

Voltage source inverter

These are the switching devices, such as insulated gate bipolar transistors (IGBTs) or MOSFETs, that control the power flow

in the inverter. The control signals generated by the ANN controller blocks determine the switching states of these devices.

HARDWARE IMPLEMENTATION

The specifications of the various components used in the hardware implementation are shown in the table. 1

Table 1: Hardware Components.

COMPONENTS	RATINGS
Transformer	Primary voltage -230V AC Secondary voltage – 9V AC and 18-0-18V AC
Positive Voltage Regulator(7805 & 7812)	5V and 12V
Negative Voltage regulator (7812)	-12V
Diode	IN4007
Capacitor	4700 μ f/16V, 4700 μ f/25V and 10 μ f/63V
Digital Signal Processor	DSPic30f2010
Driver Circuit	IR2110 (MOSFET)

The Fig. 5 shows the schematic representation of the hardware components used.



Fig. 5: Schematic representation of hardware.

Multi Output Power Supply

The power supply has three output voltages: +5V, +12V, and -12V. An AC signal is supplied to the primary winding of a transformer. The transformer's secondary winding produces two outputs: one ranging from 0V to 9V AC and the other as a center-tapped voltage of 18V-0V-18V. The secondary outputs of the

transformer are connected to a regulator circuit via a Full Bridge Rectifier and a filtering capacitor. A diode is used to convert the AC voltage into a DC voltage with AC ripples, while the capacitor is employed to eliminate these AC ripples. The regulator circuit ensures the regulation of the DC output voltage.[5]



In order to create a multilevel waveform, the AC output from each H-bridge cell at various voltage levels is connected in series. This results in a synthesized voltage waveform that is the summation of

the individual inverter outputs. The number of voltage levels present in the output phase of a cascaded inverter determines the quantity of output phase voltage levels.

Since zero voltage is shared by all inverter outputs, the overall number of voltage levels in the output waveform is determined by $2s+1$. Each individual inverter bridge is capable of producing three distinct voltage output levels. When the positive group switches are activated, the voltage across that specific bridge becomes positive. Conversely, when the negative group switches are activated, the voltage across that particular bridge becomes negative.

The IR2110 is a power MOSFET driver that operates at high voltage and high speed, offering protection against over-current conditions. Its logic inputs are compatible with standard CMOS or

LSTTL outputs, even supporting 2.5V logic levels. The output driver includes a high pulse current buffer stage to minimize cross-conduction of the driver. The protection circuitry is responsible for detecting over-current in the power transistor being driven and controlling the gate drive voltage. The shutdown process occurs on a cycle-by-cycle basis and can be adjusted using an external capacitor, which determines the time interval between detecting the over-current conditions and initiating latched shutdown. The floating channel of the IR2110 can be utilized to drive either an N-channel power MOSFET or an IGBT in either the high-side or low-side configuration, with an operational voltage of up to 500 volts.

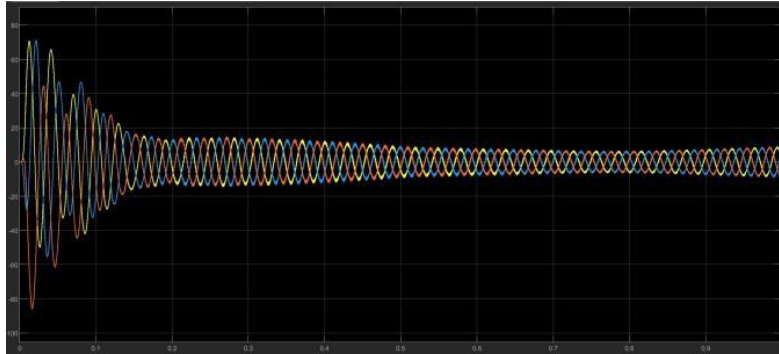
RESULTS

Fig. 7: Harmonics in supply current.

In Fig. 7 harmonics present in the supply source due to non-linear devices fed into induction motor.

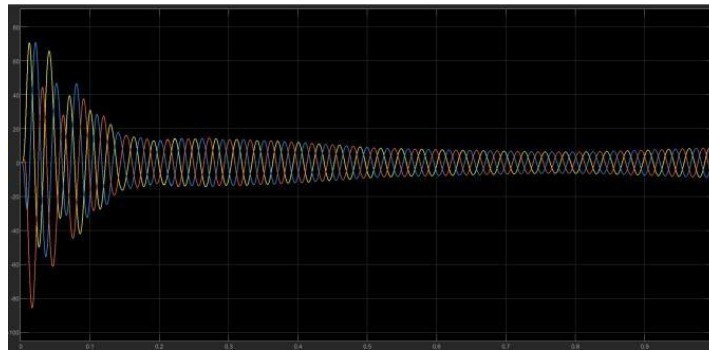


Fig. 8: Harmonics reduced current.

In Fig. 8 the harmonics induced due to non-linear loads are reduced by ANN controlled SVPWM Voltage source inverter before being fed into the induction motor.



Fig. 9: Speed characteristics of Induction motor.

In Fig. 9 the speed characteristics of induction motor with the implementation of proposed system is plotted.

CONCLUSION

The objective of this study was to utilize an Artificial Neural Network (ANN) controller in conjunction with a Space Vector Pulse Width Modulation

(SVPWM) technique to reduce supply current harmonics and torque ripples in an induction motor drive system, ultimately achieving smoother operation and enhanced performance. This paper focuses on the step-by-step development of an ANN- controlled SVPWM system applied to an induction motor. The investigation results demonstrate that the ANN controller is suited for enhancing the dynamic response of the induction motor drive. A model of a three-phase voltage source inverter based on space vector theory is discussed, and simulation results are obtained using the MATLAB/Simulink environment to assess the effectiveness of the study. Hardware implementation is carried out using DSPic30f2010 controller. However, ANN application for the proposed hardware system can be implemented to assess the real time response.

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