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Hardware Implementation of Induction Motor using ANN Controller under Low Speed Operation

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Abstract

For the high performance drives the artificial neural network based Induction motor is proposed. During the load variation, the performance of the Induction motor proves to be low. Intelligent controller provided for controlling the speed of induction motor especially with high dynamic disturbances. An effective sensorless strategy based on artificial neural network controller is developed to estimate rotor's position and to regulate the stator flux under low speed, helps to track the motor speed accurately during the whole operating region. The overall combination of this setup is simulated in the MATLAB/SIMULINK platform. Finally an experimental prototype of the proposed drive has been developed to validate the performance of Induction Motor and the dynamic speed response of Induction motor with proposed controller was estimated for various speed and found that the speed can be controlled effectively.

Keywords: *Induction motor, artificial neural network, Sensorless Speed Control*

1. Introduction

The major Household appliances include cloth washers, air conditioners, refrigerators, vacuum cleaners, freezers, etc. These appliances have [2] traditionally relied on classic electric motor technologies such as DC motors, single phase AC induction motors. These motors are typically operated at constant-speed directly from AC mains. Consumers now demand for lower energy costs, higher efficiency, better performance, reduced acoustic noise and more convenient. The traditional technologies cannot meet these demands. The Induction motor in these applications is becoming very common due to the features of high efficiency, high flux, density per unit volume and high power density due to the absence of field winding in addition the absence of brushes leads to high reliability, low maintenance requirements and electromagnetic interference problems [8].

In this paper an effective sensorless strategy based on artificial neural network is developed to estimate speed of induction motor and to regulate the stator flux under low speed and helps to track the motor speed accurately during the whole operating region. Such control reduces the drive cost, size and maintenance requirements while increasing the system reliability and robustness. To estimate the motor speed, Back Propagation Network (BPN) algorithm is used in ANN technique for whole operation. This sensorless vector controlled induction motor drives used for high performance industrial application; it improves the speed of the motor under low speed.

2. Proposed Method

In these proposed method the three phase input supply is given to rectifier which converts AC to DC and is given to the DC link inductor to smoothen the DC voltage. The DC output voltage is supplied to the three phase voltage source inverter which converts DC to AC and then given to the induction motor. In an Artificial Neural Network detects the thermal variation in the stator resistance at different operating condition. The voltage and current signals are determined from the output of the inverter and is given to the three phase to two phase transformation which consist of Clarke transformation (abc to $\alpha\beta$) and Park Transformation ($\alpha\beta$ to dq).The voltage and current signals are given to ANN controller which calculate the error and

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to get the estimated rotor position. In training data include input/target data sets is used to train the process. The block diagram of the proposed system is shown in Figure 1. At each sample the neural network output is compared with the target value and the weight correction is performed to minimize the error between the two values. The output related to change in duty cycle which is given to the PWM circuit. The PWM generator generates the pluses which are given to the gate driver. When the firing input is given to the voltage source inverter based on the turning ON and OFF inverter switch, induction motor speed is controlled even under low speed operation.

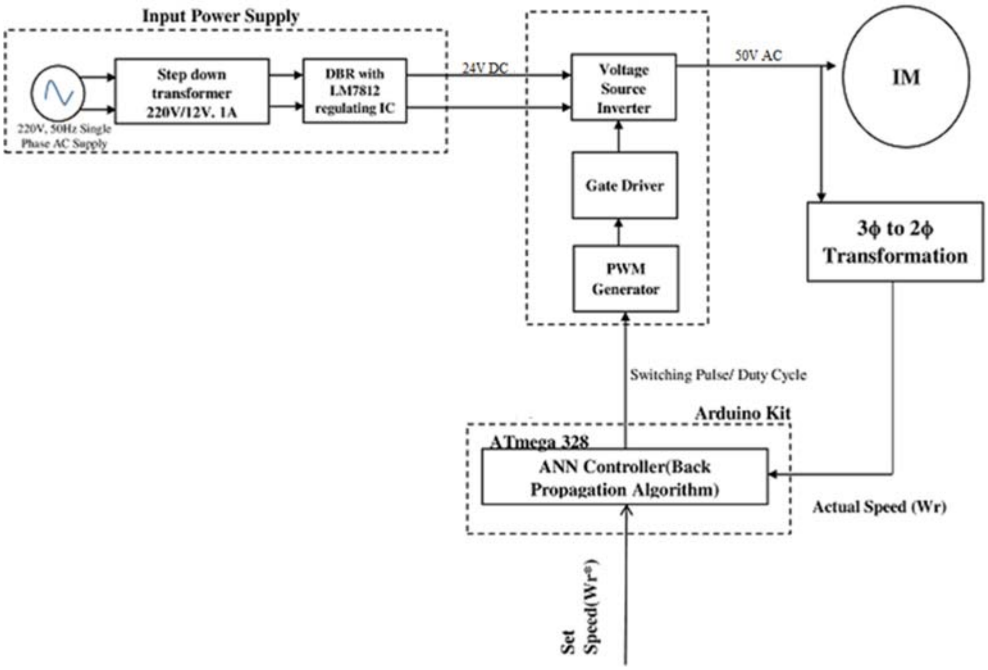


Figure 1. Block diagram of the proposed work

3. Simulation of the Proposed Method

The Simulink model of Induction motor drive using ANN controller is shown in Figure 2. Induction motor will produce different torques when the rotor is running at different speeds under various load conditions and DC bus voltage under certain turn-on and turn-off switches. In this work a feed forward neural network is created with two neurons (set speed and change in speed) in the input layer and one neuron in the output layer with one hidden layer. The activation functions used for the input neurons are pure linear and the tangent sigmoid activation function is used for output neuron. For all given training patterns the back-propagation training technique adjusts the weight and bias in all connecting links so that the difference between the actual and target output is minimized.

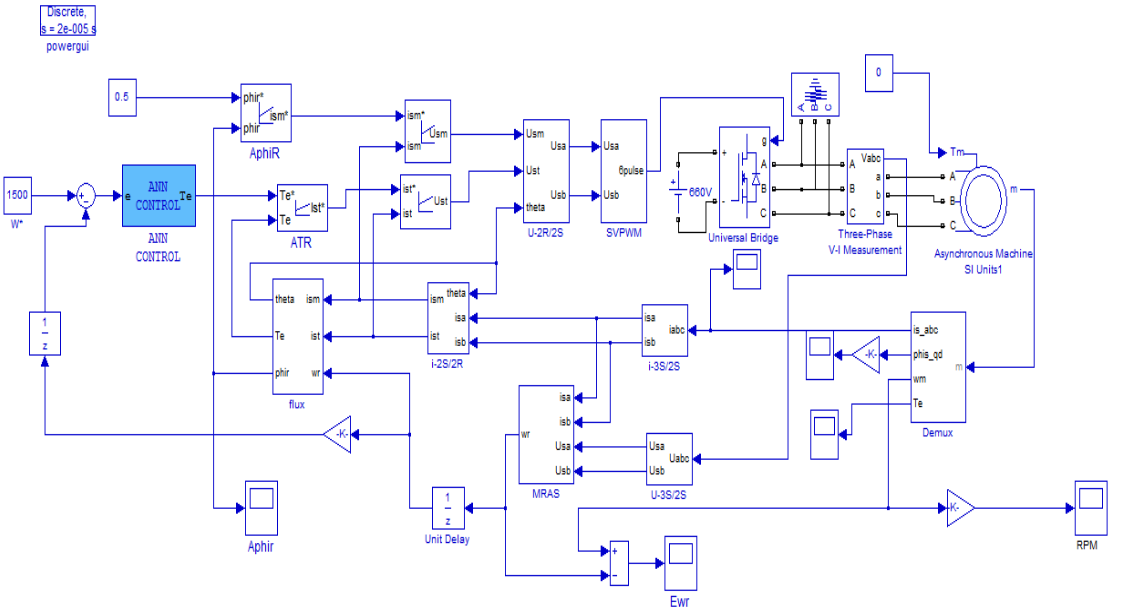


Figure 2. Simulink Diagram of Induction motor drive using ANN controller

The test system is simulated under various low speed conditions. Figure 3 show the speed response of the induction motor using ANN controller.

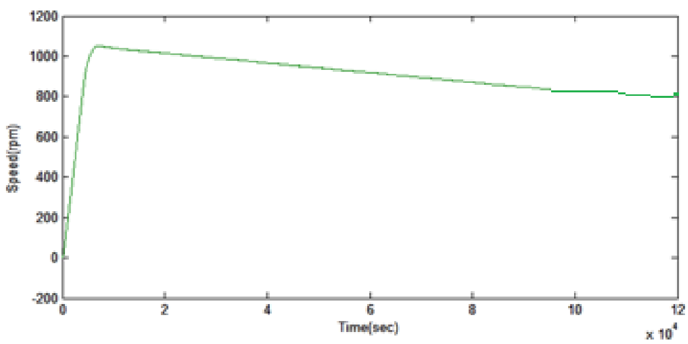
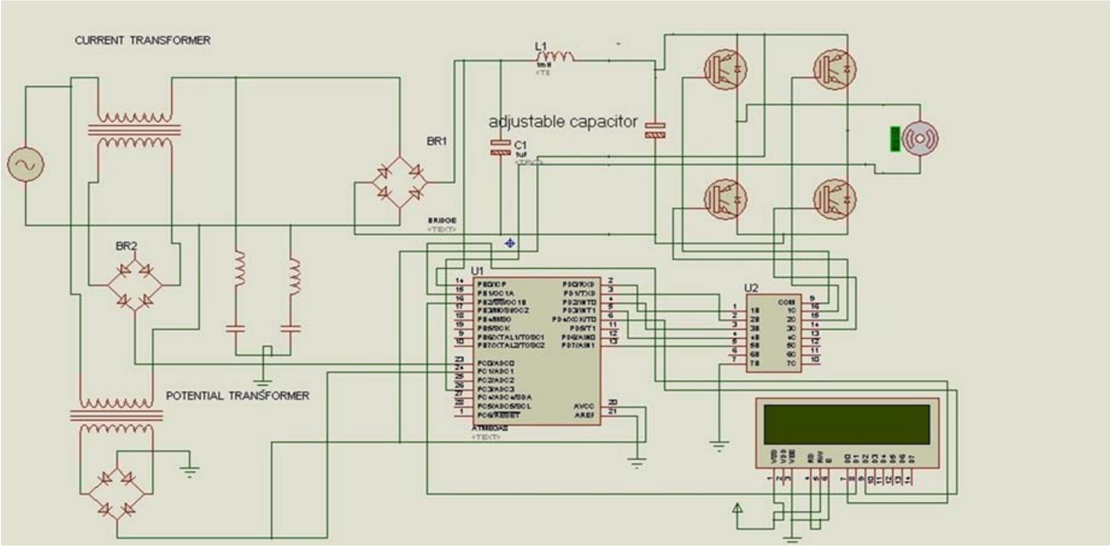


Figure 3. Speed waveform

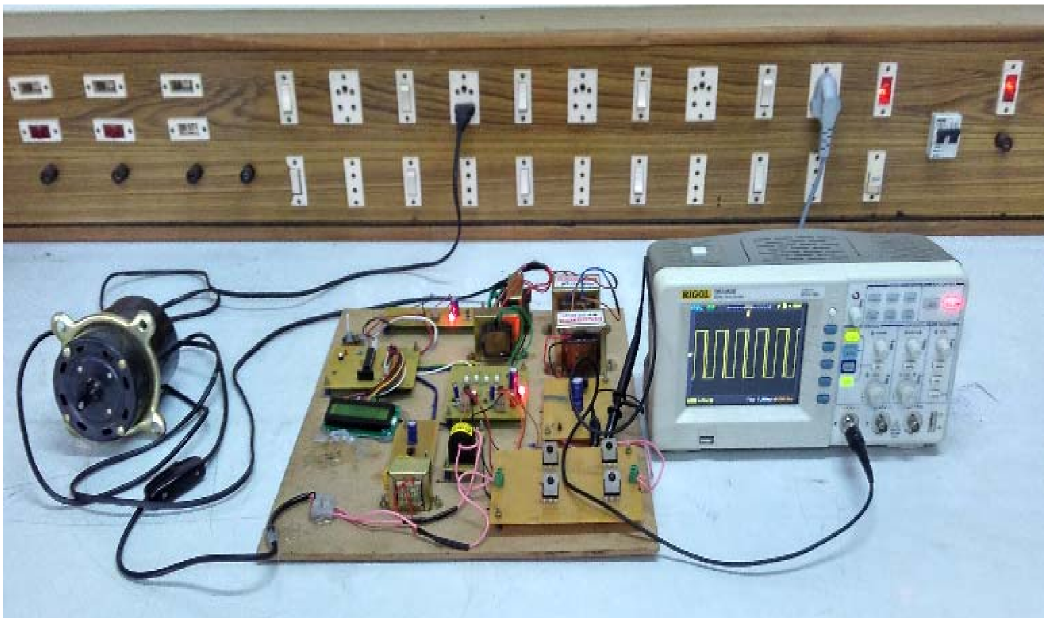
4. Hardware Implementation and discussions

Design of voltage source inverter fed induction motor drive using ANN controller is also used to eliminate the harmonics in the stator current and reduce the ripple content in generated electromagnetic torque.

The hardware results from the prototype such as input and output waveforms are analysed with the help of Digital Storage Oscilloscope. Figures 4(a) and 4(b) show the schematic diagram and overall Proposed Hardware Setup of the Induction motor using ANN controller respectively



(a)



(b)

Figures 4 Experimental setup, (a) Schematic diagram, (b) overall proposed hardware setup of the induction motor

4.1. Voltage Source Inverter

The main objective of voltage source inverters is to produce an AC output waveform from a dc power supply. This type of waveforms required in Adjustable Speed Drives, Uninterruptible Power Supplies, and voltage compensators, which are only a few applications. For sinusoidal ac output, the magnitude, frequency, and phase should be controllable. According to the type of ac output waveform, these topologies can be considered as voltage source inverter, where the independently controlled ac output is a voltage waveform. Output voltage waveform is shown in Figure 5. A 45W Single-phase induction motor fed by a voltage source type inverter was used in the experimental setup. The inverter was implemented using a four IGBT power module, AT mega microcontroller board of AT328 microcontroller performs the control algorithm and generates the PWM waveforms for the IGBT motor drive inverter

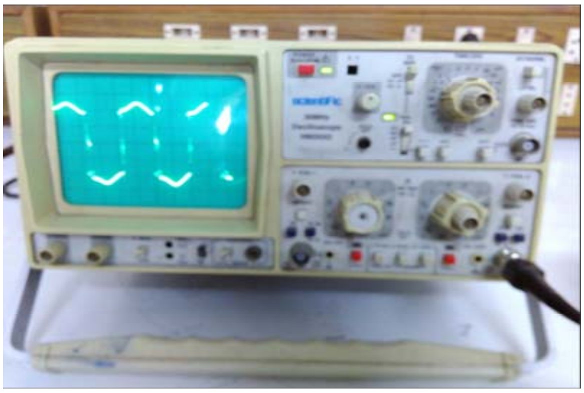


Figure 5. CRO output

4.2. Pulse Generation

The Pulse width modulation is a modulated technique that conform the width of the pulse, formally the pulse duration, based on modulator signal information. Although this modulated technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial load such as motors, the term duty cycle describes the proportion of ON time to the regular interval or period of time.

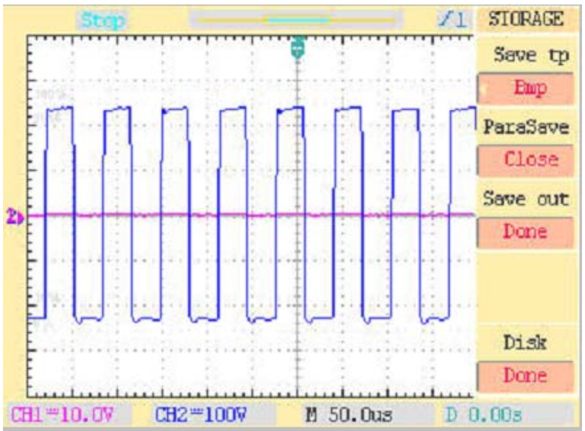
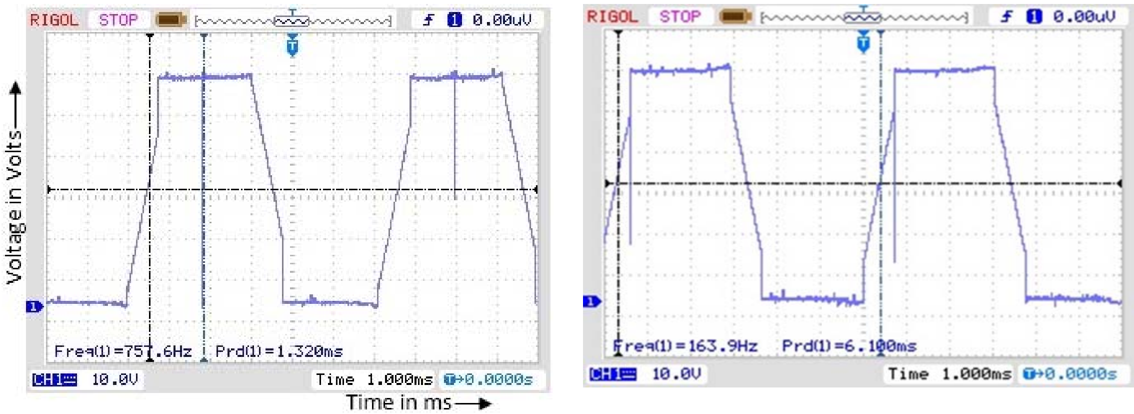


Figure 6. Switching pluses Waveform

The pulse generation of the voltage source can be obtained by using ATmega microcontroller The Figure 6 shows the input switching pluses. Based on the speed variation of the induction motor closed loop control the pulse can be varied.

4.2. Driver Circuit

The induction motor is powered with the help of driver circuit. The output of voltage source inverter is converted into DC which is further given as input to the driver circuit. The output of the driver circuit for two different operating speed of the motor is in trapezoidal shape which is shown in Figure 7(a) and 7(b).



(a) (b)

Figures 7. The output waveform for operating speed of the motor at frequency (a) 757.6 Hz, (b) 163.9 Hz

In the above waveform, the frequency denoted is for one full cycle. The induction motor is operated in variable operating speed condition. So the frequency of the motor is varied for different operating speed of the motor.

4.3. DC Link Voltage Waveform

DC link exits between a rectifier and inverter. On one end, the utility connection is rectified into a high voltage DC. On the other end, that DC is switched to generate a new AC power waveform. It's a link because it connects the input and output stages.

The term "DC link" is also used to describe the decoupling capacitor in the DC link. The switching network on the output side generates very large transients at the switching frequency. The DC link capacitor helps to keep these transients from radiating back to the input. The DC link voltage waveform from the SMPS is shown in the Figure 8.

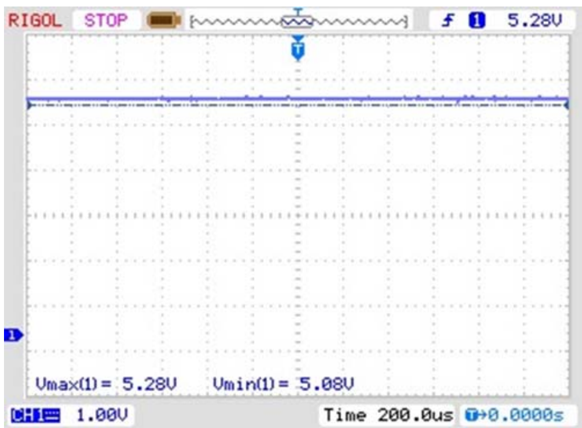


Figure 8. Output of DC Link Voltage

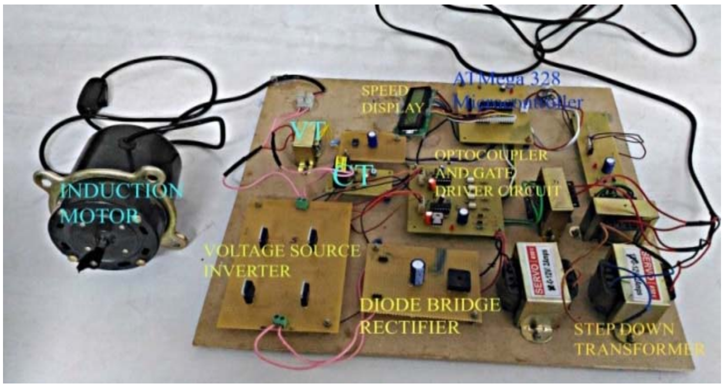
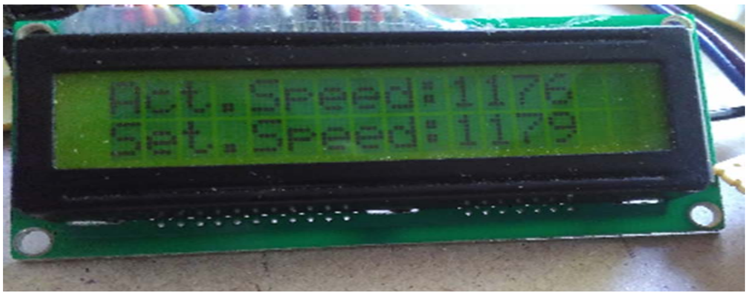


Figure 9. View of Experimental Setup

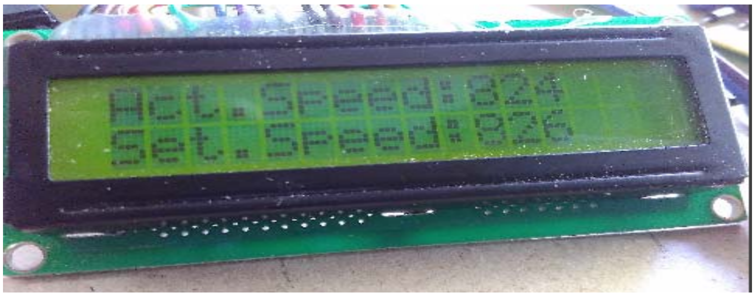
PWM waveform from microcontroller is then amplified with open collector opto coupler and fed to the DC chopper through an isolator and driver chip. The DC chopper output is given to the armature of the induction motor. The voltage transformer connected to the motor shaft gives a DC voltage proportional to the speed, and this DC voltage is fed to the ADC of the microcontroller. The Experimental setup used is given in Figure 9.

5. System under Various Operating Speed Condition

The test system is simulated under various operating condition, while the Induction motor is working under constant load condition, the current drawn from the input supply is 0.8 A. The experimental responses of an Induction motor for a step change in reference speed from to rated speed with ANN controller .



10(a)



10(b)

Figure 10(a) and 10(b). Controlling the Speed under 1179 rpm and 826 rpm respectively

Figures 10(a) and 10(b) show the controlling the speed of the induction motor using ANN controller under 1179rpm and 826rpm respectively, While the Induction motor is working under loading (LOW) load condition, the current drawn from the input supply is 0.849A. At that time the speed maintained as 824rpm (Actual Speed) for the 826rpm (Set Speed) as shown in the Figure 10(b). The designed controllers were implemented by using an Atmel microcontroller. The ratings of induction motor used are 220/230V, 45 watts, and 2400 rpm. The ANN controller's performance was tested with the induction motor. The result are compared and tabulated as shown in the Table 1.

Table 1. Analysis of Simulation Result

Charecteristics	Simulation Result	Hardware Result
Speed	Linearly varied and settled down slowly to the reference speed (870rpm) (0.065ms)	The speed of the motor is kept varies under low load condition(861rpm) by controlling DC link voltage with the help of ANN Controller(BPN) , minimum oscillation occurs
Phase Voltage	The Phase Voltage Waveform is exactly in trapezoidal shape	The Phase Voltage Waveform is in trapezoidal shape with minimum distortions

6. Conclusion

In this paper, the proposed method Voltage Source Inverter fed IM drive using ANN controller under low speed operation condition is experimentally implemented using AT mega microcontroller board of AT Mega 328 for a 45W single phase Induction motor. The proposed scheme has shown satisfactory performance for wide range of speed variation. The comparative analysis of the simulated and experimental results shows the effectiveness of the proposed drive system. The proposed scheme is recommended solution for the applicable of low power Induction motor. In the future work, renewable energy like Solar, Fuel cell can be used as the renewable energy source for this system which is useful to reduce the demand of electricity. It also reduces the pollution and greenhouse effect.

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