Variable Modulation Index PWM Inverter using AGC fed Induction Motor based WSN

Ibraheem M. Khalil, Hazem Noori Abdulrazzak, Hanaa Hameed Merzah

Abstract: ***One of most important application of industrial electronics is to keep the speed of induction motors constant at variable load. This paper gives a sufficient method to maintain the speed of induction motor constant, by changing the amplitude of sine reference signal used in generation of PWM using AGC which varied the gain according measuring the change in speed based WSN. The change in gain of reference signal will change the value of r.m.s voltage applied according to the value of change of speed, and this keeps the speed constant.***

Keywords- PWM inverter, induction motors speed control, AGC, harmonic analysis, WSN.

1. INTRODUCTION

The modulation index in PWM defined as the ratio between peak value of reference signal to a peak value of triangular carrier signal[1][2], in indusial electronics the change of modulation index of PWM will effect on the value of THD[3], as shown in Fig(1).

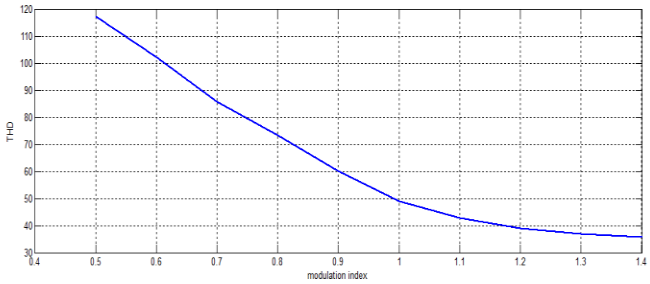

Fig (1) Relation between modulation index and THD

The change in THD result from changing the ratio between amplitude of the fundamental frequency component to amplitude of higher order harmonics appears in the spectrum of PWM output voltage, as shown in Fig(2)[4].The variation of amplitude of fundamental makes the speed of induction motor fed by PWM inverter changes;[5] however the speed of induction motor may be changes according the torque subjected to the motor, and since induction constant speed motor used in all kinds of household appliances and light industrial applications[6].

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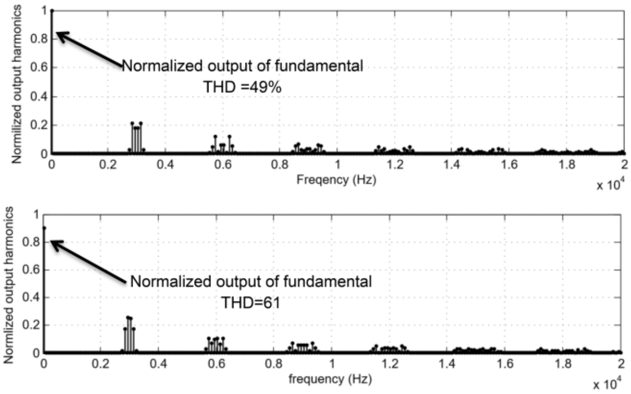

Fig (2) Relation between amplitude of fundemantal and THD

Many techniques used to control the speed of induction motors these techniques changes either the applied voltage to the motor or change the frequency of applied source supplied the induction motor each of these techniques used in different applications[7], the change in frequency used in applications at which the change in speed is high, while the change in voltage used in applications at which the change in speed is precise[8], according that a new approach has been established to measure the speed of motor based wireless network and change the applied voltage to the motor by controlling the amplitude of reference sine signal used to generate PWM voltage using Automatic Gain Control which is defined as a closed-loop feedback variable gain amplifier, the purpose AGC is to change gain to get a suitable amplitude of reference sine of PWM generator.

2. PROPOSED WORK

The proposed work depend on measuring the difference in torque that subjected at load of motor and sending the measured value using wireless sensor network, and according to change in torque ΔT which can be established according equation (1)

$$\Delta T = |T_{Nominal} - T_{New}| \quad (1)$$

According that the change in gain of AGC ΔA which can be estimated according equation (2)

$$\Delta A = |A_{Nominal} - A_{New}| \quad (2)$$

Referring to the A_{New} new reference signal with new amplitude has been generated and since the amplitude of carrier is constant the modulation index will be varied which result a variation in amplitude of PWM inverter output voltage, the proposed work schema shown in Fig (3)

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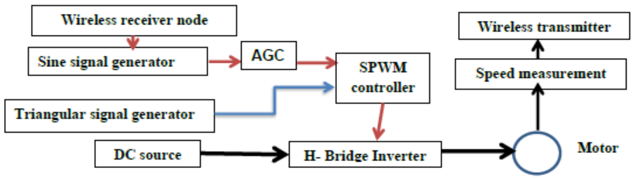

Fig (3) Block diagram for proposed system

3. WIRELESS SENSOR NETWORK STRUCTURE

A Wireless Sensor Network is a type of wireless network which consist of a large number low powered devices named sensor nodes called motes [9]. These networks certainly cover a huge number of spatially distributed, little, battery-operated, microcontroller devices that are networked to collect, process, and transfer data to the operators,[10] and it has controlled the monitoring, computing & processing. WSN has been used in many of application one of them is industrial electronics [11].

4. MATHEMATICAL MODEL

The proposed system based on the measure the change in torque corresponding to defined load at constant voltage and frequency supply source which can be established according equation (3)

$$T = \frac{constant * sE_2^2 R_2}{\sqrt{(R_2^2 + (sX_2)^2)}} = \frac{3}{2\pi N_S} \frac{sE_2^2 R_2}{\sqrt{(R_2^2 + (sX_2)^2)}} \qquad (3)$$

Where R_2 represent rotor resistance which has constant value and (s) represent the slip which has small value according that $(sX_2)^2$ is so small and it can be neglected. Therefore, $T \propto sE_2^2$ where E_2 is rotor induced e.m.f. and $E_2 \propto V$ and finally,

$$T \propto sV^2 \qquad (4)$$

Linear approximation for equation (4) used to establish a relationship between change in torque and variation in applied voltage which can be determined according equation (5)

$$V \propto \sqrt{\frac{T}{s}} \qquad (5)$$

Taking the first derivative of equation (5) with respect to T we get:

$$\frac{dV}{dT} \propto \frac{1}{2\sqrt{ST}} \qquad (6)$$

Multiplying both sides of equation (6) by ΔT where ΔT represents the corresponding change in torque which result

$$\frac{dV}{dT}\Delta T \propto \frac{1}{2\sqrt{ST}}\Delta T \qquad (7)$$

And since $\frac{dV}{dT}\Delta T$ represent the change in applied voltage added to the resolution of sensor ($\mathcal{E}_O$) equation (7) can be described as shown in equation (8)

$$\Delta V \propto \frac{1}{2\sqrt{ST}}\Delta T + \mathcal{E}_O \Delta T \qquad (8)$$

And assuming $\mathcal{E}_O = \Delta T$ then

$$\Delta V \propto \frac{1}{2\sqrt{ST}}\Delta T + \Delta T^2 \qquad (9)$$

Assuming that linear approximation suitable with change in gain of automatic gain controller and according equation (9) the change of applied voltage that fed induction motor can be changed by varying the gain of AGC (ΔA) according equation (10)

$$\Delta A \propto \frac{1}{2\sqrt{ST}}\Delta T + \Delta T^2 \qquad (10)$$

5. SIMULATION AND RESULT

5-2 Measurement and WSN side:

Two nodes were created each of these nodes content of sensor and Arduino microcontroller with wireless module. The wireless module used in this simulation is NRF24L01. The module NRF24L01T can use 125 different channels which gives a possibility to have a sensor network of 125 independently working in one place. Each channel can have up to 6 addresses (00, 01,02, 03, 04, 05), or each unit can communicate with up to 6 other units at the same time. In this work NRF24L01 used because it is considered an expandable module so it's easy to increase the nodes if the system needs to increase the number of motors. The system simulated by two parts, the first one is NRF24L01 Transmitter, in this part NRF24L01 (2401 MHz) was used with address (00), so it can communicate with AGC side wirelessly at the above frequency. Assuming that the distance distance between AGC and speed measurement side is about 30 to 50 meter. the other part of WSN is NRF24L01 Receiver, and in this side the NRF24L01 (2401MHz) with address (01) is used as a client of data delivery. The received speed Value will be forwarded to receiver in order to adjust the gain of AGC then change value of modulation Index, and finally change the value of applied voltage across the induction motor.The structure of NRF24L01 connection described as shown in Fig(4).

Fig (4) connection structure of of NRF24L01

5-2 Power side:

Due to linearity of equation explained in mathematical model, the change in torque which can be subjected to the motor is proportional to speed, at constant supplied voltage of source and when the torque decreases by 10 %, and becomes 0.9 of its original value, the speed of the induction motor will increase, and when torque increased by 10%, and becomes 1.1 from its original value, therefore the speed will reduce. Hence we can say that (± 20%) change in speed result from variation in torque by about (∓20%), assuming that the induction motor operates as nominal torque and applied voltage of 220 r.m.s the resultant speed is 3600 rpm the variation in torque and speed result at constant applied voltage represented as shown in Fig (5).

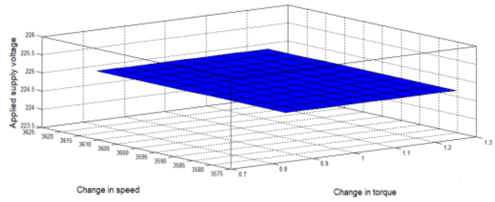

Fig (5) change in applied voltage and applied torque against change in speed

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The proposed technique suggest that the torque subjected to the motor change by (± 20 %) which is measured using node of wireless sensor network, and according to this change the gain of automatic gain controller will change in order to keep the speed of induction motor constant, as shown in Fig (6).

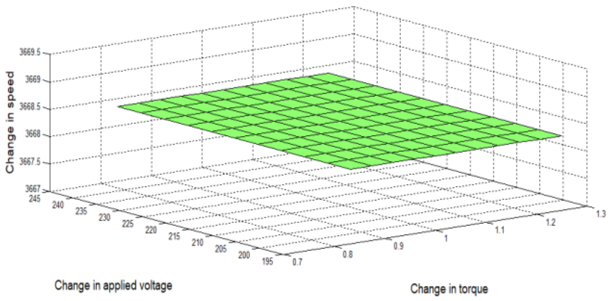

Fig (6) change in applied voltage and modulation index against change in speed

Referring to Fig (5) the change in speed of motor is became is very small with respect to change in regular PWM controller, the change in voltage result from the variation of gain of AGC which result a change in value of r.m.s. value of the supply voltage the variation in gain against the r.m.s. voltage of the supply shown in Fig (7).

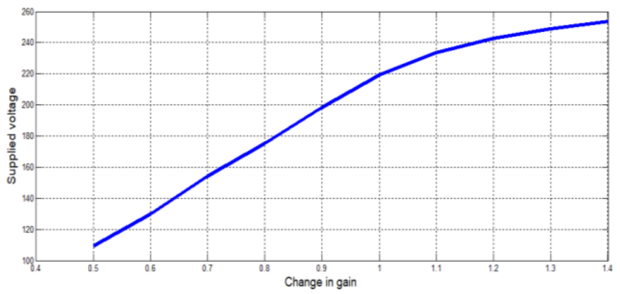

Fig (7) change in applied voltage and against change in gain

6. CONCLUSION

The proposed system was investigated to give enhanced control on speed of induction motor at linear change in subjected torque, by changing the modulation index of PWM pulses that switch ON/ OFF the H-bridge inverter that supplied the induction motor. At regular controllers the change in torque result in a wide range of speed variation, while for the proposed technique for the same change in torque there were precise change in motor speed.

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