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Implementation of TMS320f28335 DSP code based on SVPWM technique for driving VSI with induction motor

Enas Dawood Hassan[1], Khalid Ghadban Mohammed[1], Inaam Ibrahim Ali[2]
[1]College of Engineering, University of Diyala, Diyala, Iraq
[2]Electrical Engineering Department, University of Technology, Baghdad, Iraq

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ABSTRACT

The ability to control the speed of three-phase induction motors is a complex and arduous task using conventional control methods because the induction motor still inherits traditional design problems such as nonlinear and multivariate reactive dynamic behavior that leads to difficult design of the motor's mathematical model, and the strict overlap between decades of mathematical parameters. This causes more complex relationships with changing loads. This complexity results in unacceptable behavior of the system, and the difficulty of controlling its speed without affecting the torque, and thus the specific calculations of engine efficiency are almost low. Therefore, the current research provides the implementation of devices for the V/f control method that is fed via Inverter of the voltage source using the new generation of digital signal processor TMS320F28335 according to the theory of space vector pulse width modulation (SVPWM) for the application of motor control. The results obtained from practical experience show the possibility of obtaining a wide range of control and thus reduce the damage to the system in the event of the load thus ensuring the reliability of the proposed control scheme is built on DSP.

Corresponding Author:

Khalid G. Mohammed
Departement of Electrical and Computer Engineering, University of Diyala
Baqubah, Diyala, Iraq
Email: khalid_alkaisee@engineering.uodiyala.edu.iq

1. INTRODUCTION

In modern industrialized nations, more than half of the total electrical energy used is converted into mechanical energy by the induction motor [1], [2]. Today induction motors are widely used in industrial [3], household and commercial equipment and devices such as centrifugal pumps, elevators, compressors, punch presses due to their high reliability and durability, relatively low cost, simple structure and easy maintenance which are free of charge [4], [5]. Controlling an induction motor (IM) is challenging, especially at the mechanical load changes due to of its nonlinear dynamics, which are inherently complicated. which leads to unacceptable behavior of the system, and therefore the efficiency of the motor will be almost low, as it is difficult to obtain appropriate parameters to control it [6], [7]. There are several control methods to control the nonlinear dynamics of three-phase induction motor, based on IM's load characteristics. The vector control or field-oriented control (FOC) method approach may be preferred by certain researchers as a result of its quick response [8]. This sort of system allows for complete control of stator currents or torque. However, with regard to embedded system implementation, it rises complexity and handling time, making lowering system costs extremely challenging with system diagnostics under defective circumstances [9]. To minimize system complexity, direct torque control (DTC) on FOC has been presented as an optimum between complexity and cost approach [10]. The DTC allows direct comparison of load and motor torque characteristics, but it raises torque response ripple. Meanwhile, V/f control provides a straight simple solution to control issues with minimal steady-state error [11]. V/f control include many advantages such as quick response, parameter independence, simplicity of design, ease of implementation, low cost, speed control without sensors [12], [13].

The hardware foundation and control method of electrical drives determine the quality of the generated end user product. Hardware selection is a crucial element of the motor development process, and it has a significant impact on cost [14], [15]. Several research have been carried out in order to enhance the IM controller through the development of vector and V/f (scalar) control, as well as contemporary microcomputers and the power electronic systems, like a microprocessor, digital signal processor (DSP), where the combination of "high-performance DSP and power electronics devices" has enabled superior control over the field of induction motors [16], [17]. The DSP-based technique has been shown to be the most effective and the capacity to rapidly and simply conduct the required signal computations because of its better computing capabilities, lower power consumption, quicker design cycle, embedded processor, and higher density than other processors [18]. Furthermore, the switching methods by inverter play a significant role in the expansion and reinforcement of IM control by decreasing harmonics 19]-[21] ,The space vector PWM (SVPWM) technique is one of the greatest switching methods efficient used in inverter control technology as a result of its capacity to reduce harmonic distortion [22]-[24].Also a number of research on the proportional-integral-derivative (PID) controllers have been carried out, The PI controller is the most commonly utilized of these controllers for linear control due to it has the capacity to adjust itself to needs of the system [25], [26].

In this present study, a scalar control (V/f) method was chosen to control the speed of a three-phase induction motor (3PIM) using a new generation DSP TMS320F28335 through a VSI voltage source transformer. The control algorithm is designed using code composer studio (CCS) according to the space vector theory of pulse width modulation (SVPWM) with the PI controller of the pulse bandwidth equipped with this microprocessor and compared to the return pulse of the encoder in order to create and apply a closed back feed system for good stability performance of Speed applied to 3 PIM shaft regardless of mechanical loads changed. After applying load to the induction motor, the DSP kit TMS320F28335 operates on altering the system's speed.

This paper marshaled as follows section 2 depict the construction of proposed system while section 3 demonstrates design of the speed control of IM drive using DSP TMS320F28335 based on SVPWM. Section 4 presents the control algorithm. Section 6 illustrates the proposed scheme's hardware implementation. Section 7 depicts the experimental results and section 8 which is the conclusion.

2. PROPOSED SYSTEM

The block diagram of the proposed system construction as shown in Figure 1 includes the construction and hardware layout of the DSP TMS320F28335-based for scalar control process. (DSP) enable high-speed and more precise control for induction machine under a variety of load situations. The SVPWM switching method and the PI speed controller was used to control the TIM motor. During V/f control, the stator voltage and frequency govern the induction motor's speed in such a way that the air gap flux is maintained at the required value at the steady state as depicted, the complete system is made up of the power circuit, the control circuit, and the feedback sensor circuit. DSP320F28335 belongs to the driver and control devices category. The inverter, which is built of IGBTs, is part of the power circuit. To perceive the output, encoders are attached.

The power circuit incorporates a three autotransformer to manage the voltage of the dc connection. A three-phase power rectifier is connected to an autotransformer to provide a DC supply.The power circuit regulates the flow of electricity from the mains to the load. This system can handle voltages in the 400–415 VAC and 600 VDC ranges.On the other hand, three-phase voltage source (VSI) inverter is employ to manage the power flow to the load. VSI module comprised of the 6 IGBTs linked, 27 ampere, 600 volt IGBT, part number: G4PC50UD, IRG4PC50UD as indicated in Figure 2.

The gate drive circuit is designed using IC Type SN74LS14N for the purpose of boosting the power level to emit pulses of the IGBT switches of the designed VSI inverter, as well as for isolation between the power circuit and the control circuit, during this work the optocoupler A3120 used as isolation and drive circuit for IGBT. Actually, the designed gate motor circuit corresponds to the PWM output channels related to the DSP. The generated signals are applied to the inverter of the voltage source, which in turn controls the motor speed according to the proposed system.

For the purpose of measuring the motor speed, an optical encoder is used to measure the position of the rotor as it is directly attached to the rotor shaft. The feedback from the optical encoder arrives at the DSP following signal conditioning. DSP is tie up to computer loaded with software CCS software. The suggested compensator creates the drive system's speed command. The DSP signals be created based on the speed reaction and control algorithm. The inverter receives switching pulses from the DSP control board's digital output. Those digital signals are sent during the isolation and drive circuit to trigger the three-phase inverter's IGBTs. The signal conditioning device processes the speed signals acquired by the sensors before feeding them to the DSP control board's I/O port. The IM is designed in the shape of a star, with three supply points and a balanced load. As a result, IM can be linked to a three-legged VSI. The IM and the magnetic powder brake is employ for check different loading conditions.

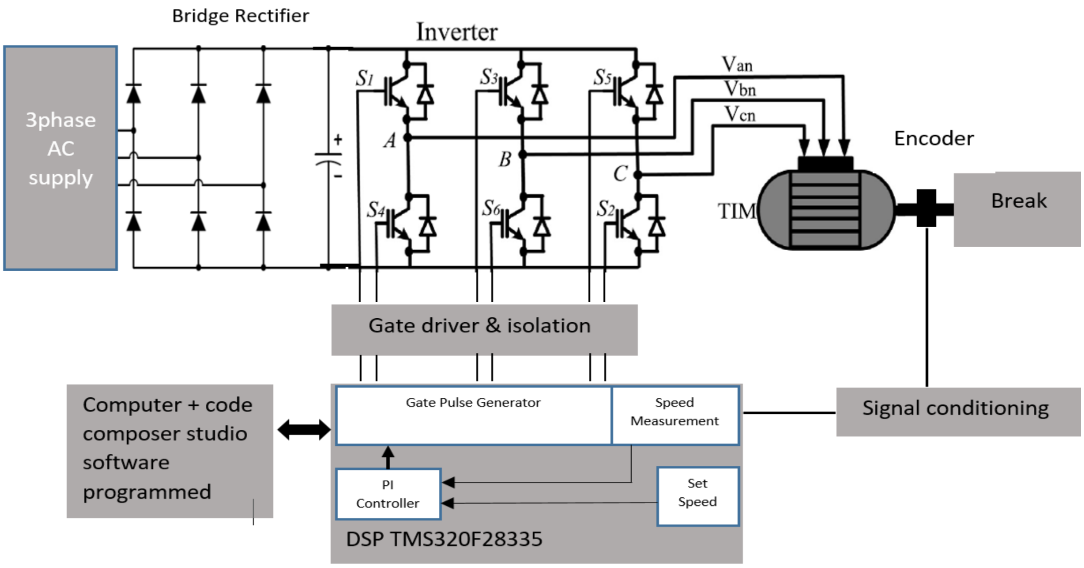


Figure 1. Proposed system

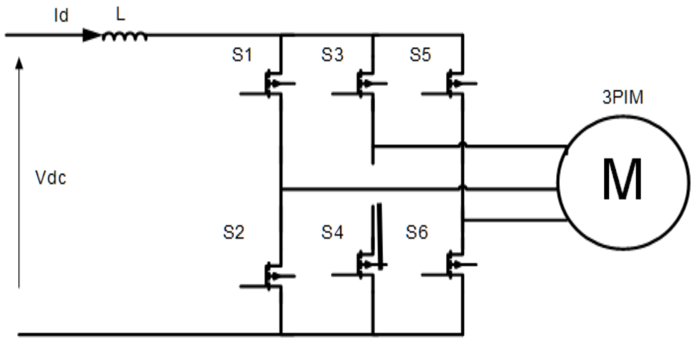


Figure 2. Inverter circuit diagram

3. PROPOSED CONTROLLER DESIGN

The control technology is one of the most paramount parts of the driving process. The main purpose of the proposed control system as shown in Figure 1 to run the three-phase induction motor at the desired speed during a variable load condition. The proposed engine speed control system was developed based on the control algorithm of DSP TMS320F28335 by employ CCS software. The control family program window provides various libraries that can be used during the development process. The control system takes the speed reference signal as input through the apparent diffusion coefficient (ADC) pins. This signal is processed outside the DSP using analog equipment. For V/f control, this feedback signal is utilized to correct for speed and voltage reference.This signal are supplied prior to the creation of PWM to ensure that the operational criteria are met.So the control system takes inputs from a reference speed to run it at this speed. In other words, the control system provides the required amount of supply voltage at the motor side by means of the inverter of the voltage source. Terminal voltage The synchronous velocity of the stator magnetic field is determined by the terminal voltage according to the reference velocity. The rotor follows the magnetic field associated with the stator and operates at close to the velocity of that synchronous magnetic field. During turbulence on the motor, such as a change in the mechanical load or changes in the reference speed, the rotor speed will drop below the required frequency, so the difference between the reference speed and the real speed will increase. Within the proposed control system, the PI controller is a good choice for the system to detect the error in the returned speed signal and solve the error by producing a compensation signal to be able to obtain the desired speed through the use of the control algorithm. The error caused by the difference between the required speed and the actual speed The PI controller processes the fault and produces an ideal duty cycle of the PWM control signal. SVM technology like SPWM is utilized to produce digital PWM signal via ePWM outputs. The SVPWM technology takes three input values (Van, Vbn, and Vcn) and produces six pulse width adjustments of the IGBT three-phase inverter consisting of six IGBTs used to control a three-phase induction motor.

SVM is implemented in plane by adding a VREF vector to three steps of voltage signals that are sinusoidal in α–β. The clark transform is used to rotate this vector to transform three-phase quantities into constant two-phase quantities. Quantities are converted from an axle reference frame to a synchronous rotating reference frame, using park transformation. Space vector modulation diagram and statement of switch state vectors for SVPWM through Figure 3 and Table 1. The SVPWM control algorithm that used speed motor control shown in Figure 4.

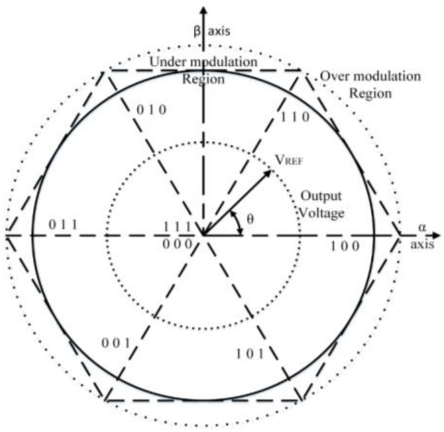


Figure 3. Space vector modulation diagram

Table 1. Statement of switch state vectors for SVPWM

Vector	A+	B+	C+	A-	B-	C-	Vab	Vbc	Vca
V0(000)	OFF	OFF	OFF	ON	ON	ON	0	0	0
V1(100)	ON	OFF	OFF	OFF	ON	ON	Vdc	0	-Vdc
V2(110)	ON	ON	OFF	OFF	OFF	ON	0	Vdc	-Vdc
V3(010)	OFF	ON	OFF	ON	OFF	ON	-Vdc	Vdc	0
V4(011)	OFF	ON	ON	ON	OFF	OFF	-Vdc	0	Vdc
V5(001)	OFF	OFF	ON	ON	ON	OFF	0	-Vdc	Vdc
V6(101)	ON	OFF	ON	OFF	ON	OFF	Vdc	-Vdc	0
V7(111)	ON	ON	ON	OFF	OFF	OFF	0	0	0

4. ALGORITHM DEVELOPMENT

The control algorithm is designed by CCS. The initialization of all essential modules is the first step in this control technique.CPU timer, GPIO, ADC, and ePWM units are among these modules.An endless loop is used in this software to conduct a continuous operation. To switch on closed loop activity, external controls are provided through GPIO. The ADC features a 10 kHz sampling rate and a 5 kHz carrier frequency. Interpret service routines (ISR) is in charge of the program flow in this way. The ePWM1 interrupt provides the ISR.The scalar control program uses created functions that are based on predetermined jobs in the control suite software to execute DSP. The PI jobs construct are setup on section 3. Figure 4 is a flow chart for a created program in CCS.

The scalar control algorithm begins by producing digital switch states by modernization the SVPWM reference. At the end of every instruction, a fresh sample is taken to process using the scalar control algorithm. This algorithm is loaded into a DSP to test the control scheme's performance on a hardware level.

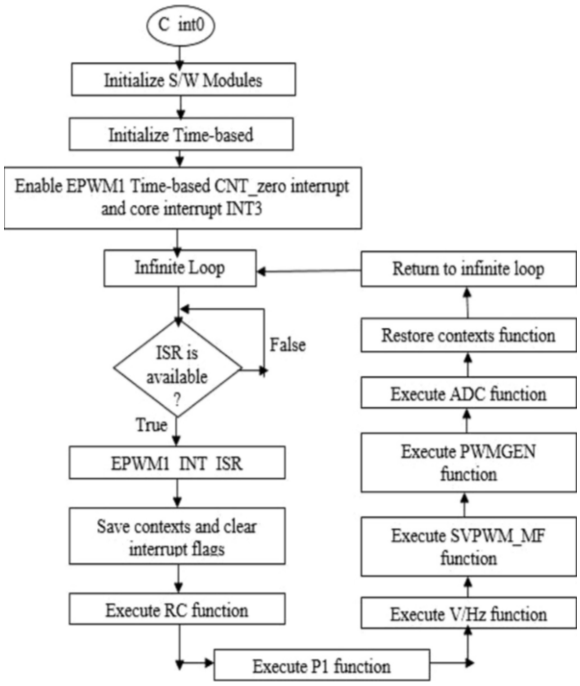


Figure 4. Flowchart displays the sequence of operations in the control kit

5. HARDWARE RESULTS AND DISCUSSION

A trial of the IM motor was implemented by the digital signal processor TMS320F28335 with SVPWM technique and PI controller to determine the proposed speed control scheme efficacy under a variety of loading situations. The testing was conducted on CCS program to develop and construct codes for the DSP. The main characteristics of the series DSP TMS320F28335 includes a 150 MHz high clock frequency,12 analog to digital (A/D) converters high speed,16 PWM channels which for generating the PWM signal required for the application, the encoder unit (QEP) used for the engine speed measurement function, 32-bit floating point unit and 256 KB SRAM memory 512 KB flash memory and a common JTAG control interface that supports real-time error handling. A parameter of the IM for 3-phase, four poles, squirrel cage, 1390 rpm, 415 V, 50 Hz,1HP (0.75kw) and 2 Amp rated current (star connection) were used in this study. A 3- phase voltage source inverter was employed to lead the IM by a switching frequency of 1 kHz and a dead time of 2 µs.

For the implementation of the proposed control scheme with a digital signal processor TMS320F28335, Figure 5(a) shows the schematic design of the partial gate driver board suggested that receives DSP signals and Figure 5(b) illustrates the panel control which includes the gate driver with switches IGBTs and a DSP device. While Figure 5(c) shows a model of complete devices for the proposed system that was developed in the laboratory. Figure 5(d) presents the experimental model of V/f method to control of speed based on DSP tms320f28335 for the IM motor. A DSP board was integrated with the inverter and connected to a computer through a JTAG connection. The developed a C-code program is created to use in the CCS development platform. The DSP chip was then programmed with this code, which was utilized to generate the correct switching of the IGBTs. In this research, a rotary encoder was employed. The rotary encoder detects rotor shift speed and transforms it to digital output signals. The encoder's output signals are utilized to monitor and control the TIM drive's speed. As a result, it is an integral part of the proposed control scheme.

When the power is switched on, the dc voltage of inverter is determined to 300 V. The DSP kit provides six SVPWM signals to the IGBT gates. This signals pass during the gate drives to the IGBT gates in the VSI to provide the IM with the power it requires. Then the motor begins to run at its basic speed.but Its speed diminishes when it is loaded. As a result, an encoder detects the reduction in speed and sends it to the DSP kit. Now, the DSP TMS320F28335 executes the program and outputs the IM module signal. As a result, the voltage necessary to maintain the base speed will increase. thereby, the motor's speed remains constant post the load is placed. In this way, speed control of the induction motor is achieved.

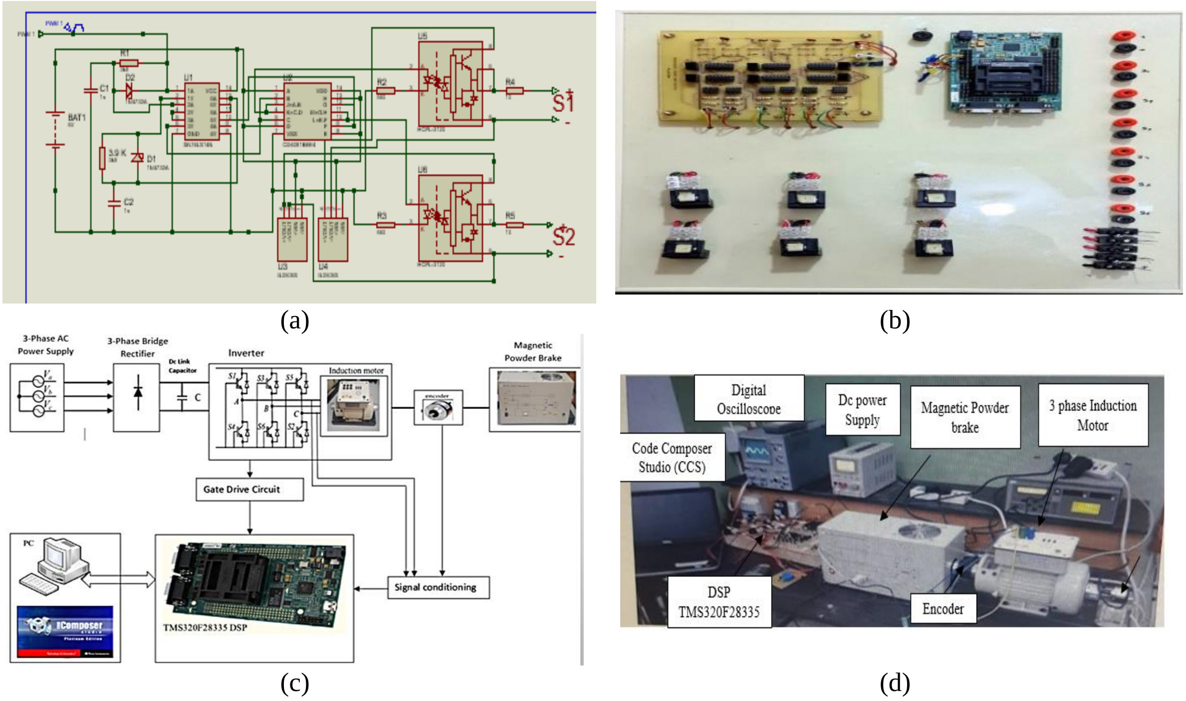
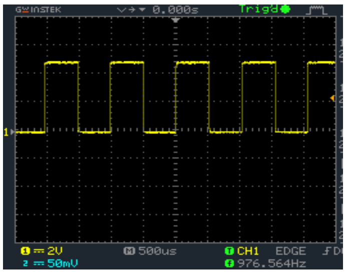


Figure 5. Experiment setup of V/f control IM drive: (a) schematic design, (b) gate driver with switches IGBTs and a DSP device, (c) model of complete system, and (d) experimental model

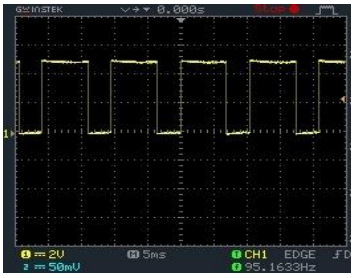
6. RESULTS AND DISCUSSION

The experimental results are obtained by implementing the practical experiment of the proposed speed control scheme on the basis of constant velocity with variable mechanical load states. PWM pulses are generated via the SVPWM process, which includes obtaining a reference voltage by simplifying the state of the SVM. Figures 6(a)-6(f) shows the difference in the duty cycles of the pulses modified under the different loads placed on the motor shaft because the controller changes the duty cycle of the control signal in the PWM in order to obtain the required speed. Table 2 includes six tests showing variation in the actual speed response due to increased load (current drawing process such as torque) and changes in PWM periodic time (on/off cycle) while the controller is absent.

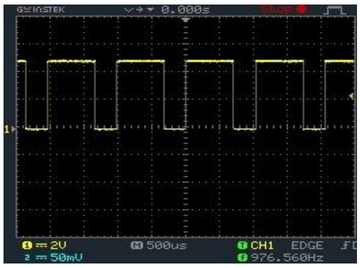
Test 1 as shown in Table 2 and Figure 6(a). It shows the normal operation of the motor at a speed of 381 rpm without load (T=0), it can be seen that the period of the PWM signal is about 500 µs on, 500 µs off and the drawn current is about 0.6 Amp. Figure 7 shows the shape of the A phase reference voltage delivered to 3 PIM. Test 2 shows the first load condition of the motor as shown in Table 2 and Figure 6(b). It is noted here that if a mechanical load of 0.1 pu is applied to the motor shaft, the speed of the induction motor is reduced to 378 rpm and the value of the drawn current is about 1 Amp, that is, an increase of 167% compared to the no-load as shown in Test 1. It can be seen that the period of the PWM signal is about 670 µs in the on mode and 330 in the off mode. Test 3 shows the second state of the load as shown in Table 2 and Figure 6(c). It is noted here that if the value of the mechanical load is increased to 0.15 p.u, the speed is reduced to 376 rpm with the value of the current drawn. Which amounted to 1.2 Amp, that is, an increase of 200% compared to the no-load test. It can be seen that the period of the PWM signal is about 700 µs on, 300 µs off. Test 4 shows the third state of the load as shown in Table 2 and Figure 6(d). It is noted here that if the mechanical load on the motor shaft is increased to a value of 0.2 p.u, the speed has decreased to 370 revolutions per minute, and the value of the current drawn It reached 1.6 Amp, that is, an increase of 267% compared to the no-load test. It can be seen that the period of the PWM signal is 730 µs on, 270 µs off. Test 5 shows the fourth state of the load as shown in Table 2 and Figure 6(e). It is noted here that if the mechanical load on the motor shaft is increased to a value of 0.25 p.u, the speed has decreased to 352 revolutions per minute, and the value of the current drawn It reached 1.8 Amp, that is, an increase of 300% compared to the no-load test. It can be seen that the period of the PWM signal is 820 µs on, 180 µs off. Test 6 shows the fifth state of the load as shown in Table 2 and Figure 6(f). It is noted here that if the mechanical load on the motor shaft is increased to a value of 0.3 p.u, the speed has decreased to 346 revolutions per minute, and the value of the current drawn It reached 1.8 Amp, that is, an increase of 317% compared to the no-load test. It can be seen that the period of the PWM signal is 870 µs on, 130 µs off.



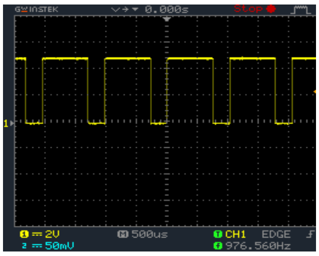
(a)



(b)

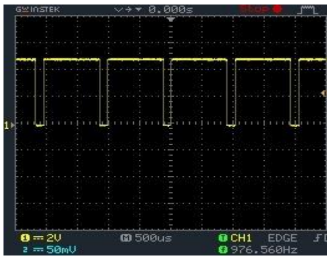


(c)



(d)

(e)



(f)

Figure 6. Different duty cycles under the different loads (a) no load, (b) 0.1 p.u load, (c) 0.15 p.u load, (d) 0.2 p.u load, (e) 0.25 p.u load, and (f) 0.3 p.u load are applied on the motor shaft

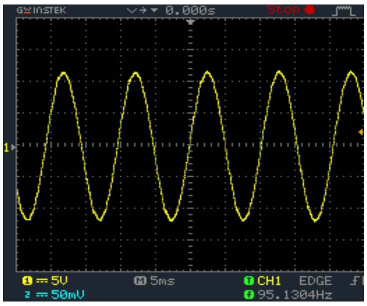


Figure 7. Sinusoidal voltage which is delivered to the 3 PIM

Table 2. Practical results drawn current as torque with the shaft speed of 3 PSM without controller (open control system)

PWM Periodic time	Speed (rpm)	Drawn Current I (average) Amp.
500µs ON, 500 µs OFF, Vamp=5 V	381	0.6
670µs ON, 330 µs OFF, Vamp=5 V	378	1
700µs ON, 300 µs OFF, Vamp=5 V	376	1.2
730µs ON, 270 µs OFF, Vamp=5 V	370	1.6
820µs ON, 180 µs OFF, Vamp=5 V	352	1.8
870µs ON, 130 µs OFF, Vamp=5 V	346	1.9

Table 3 summarizes the system's speed response to the standard control scheme and changes in the PWM periodic time while the controller is in place during progressive load operation. The set of speed controllers used to manage the process of keeping the shaft speed constant at 381 rpm adjusted the duty cycles during the six test phases, Starting from the loading condition as in Table 3, the duty cycles were adjusted to (134, 140, 150, 164, 174)% respectively compared to those in the load test shown in Table 2. The IM motor's speed stability was maintained on 381 rpm, despite these variations under varied loads.

Figure 8 depicts the speed response while applying variable loads in the absence of the control unit, where we note that increasing the loads leads to higher values of the drawn currents (0.6, 1, 1.2, 1.6, 1.8, 1.9) Amp corresponding to the response speed (381, 378, 376, 370, 352, 346) rpm. The deviation in velocity increases with the gradual increase of mechanical load which leads to an increase in the drawn current. Figure 9 depicts the speed response while applying variable loads to the engine lip depending on the control unit. We can notice the stability of the speed at the value of 381 rpm with the gradual increase of the mechanical load, which leads to higher values of the current drawn (0.6, 1, 1.2, 1.6, 1.8, 1.9) Amp .

Table 3. Practical results drawn current as torque with the shaft speed of 3 PSM with controller (feedback control system)

PWM Periodic time	Speed (rpm)	Drawn Current I (average) Amp
500µs ON, 500 µs OFF, Vamp=5 V	381	0.6
500µs ON, 500 µs OFF, Vamp=5 V	381	1
500µs ON, 500 µs OFF, Vamp=5 V	381	1.2
500µs ON, 500 µs OFF, Vamp=5 V	381	1.6
500µs ON, 500 µs OFF, Vamp=5 V	381	1.8
500µs ON, 500 µs OFF, Vamp=5 V	381	1.9

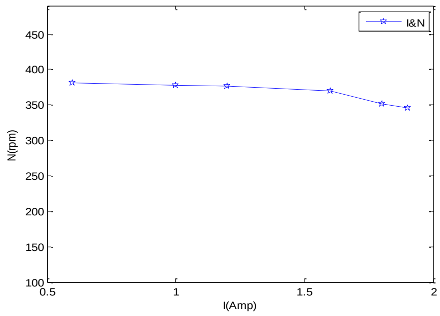


Figure 8. Speed of 3 PIM with variable loads in open control system

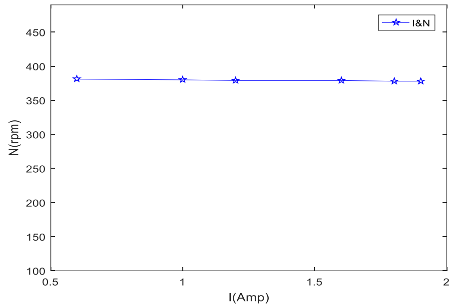


Figure 9. Speed of 3 PIM with variable loads in feedback control system

7. CONCLUSION

By implementing DSP control TMS320F28335 based on SVPWM technology on 3 PIM based on estimation of velocity response efficiency by changing the reference velocity with changing the loads imposed on the motor shaft in two states during the absence of the controller and during its presence in both cases respectively the performance feasibility of the control system is included in classification system by checking the system during sudden changes in the load at a constant speed. It is clear that the speed changed from 381 rpm to 346 rpm due to the change of load on the shaft upwards. The increased mechanical load on the motor shaft causes more current to be drawn to the source (battery) side so that direct wash current (Idc) ranges from 0.6 A to 1.9 A. As for the conduct of the second test with the presence of the control encoder, it is clear from the test results that the column speed was maintained at 360 rpm, which proves that the set of speed control tools used to manage the process has achieved the desired goal of the presented research.

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BIOGRAPHIES OF AUTHORS

Enas Dawood Hassan is a lecturer in Electronics Engineering Department at the University of Diyala, Iraq. She received his MSc.Eng. degree in Electrical Engineering from University of Technology in 2022. Her field of research covers a wide range of subjects in Power System stability FACTS Devices Power Quality and Renewable Energy. She can be contacted at email: enashassan808@gmail.com.

Assit Prof. Dr. Engg. Khalid Ghadban Mohammed is a PhD researcher in the Department of Electrical Power Engineering at University Tenaga Nasional, Malaysia. He has ten years of industrial experience in repairing and maintenance of several types of electrical machines. He has published many papers works in 2007 and 2019 containing many new practical correlations for the design of single and three phase induction motors. He has authored three practical experimentation books in electrical circuits and machines and has been teaching since 2009 in the College of Engineering, Diyala University, Iraq. He can be contacted at email: khalid_alkaisee@engineering.uodiyala.edu.iq.

Inaam Ibrahim Ali received her M.Sc. degree in Electrical Power Engineering from University of Technology, Baghdad-Iraq, in 2002. She was awarded a PhD degree from University of Technology in 2010. Since 2002, she has been a Lecturer in Electrical Engineering in the Department of Engineering at the University of Technology, where she teaches Electrical Circuits, Electrical Machines, Power Systems Engineering, power electronics and Power Systems Analysis. Her field of research covers a wide range of subjects in Power System stability FACTS Devices Power Quality and Renewable Energy. She can be contacted at email: 30037@uotechnology.edu.iq.