Matlab Simulation of Variable Voltage Frequency Drive for 3-Phase Induction Motor Using Pulse Width Modulation (PWM) Technique

Muddasar Ali, Khadija Jalal, M. Ejaz Hassan

***Abstract:** Induction motors are widely used in many industrial processes. The speed of AC motors remains constant because it takes rated power from supply and therefore it causes problems when less motor speed is needed. Improvement in power electronics technology though advancements in semiconductor electronic devices have led to development of variable frequency motor drive (VFD), an electronic device used to control speed of an induction motor with increased efficiency, reliability and low cost. This paper carries out simulation of a variable frequency drive using MATLAB/SIMULINK model. Control of speed of induction motor was successfully achieved from zero to nominal speed by varying the frequency of Pulse width modulation (PWM) Generator.*

***Keywords:** PWM, VFD, Variable frequency drive, Pulse width modulation.*

I. INTRODUCTION

Induction motors are used in many industries because of its reduced cost and reliability. In industrial applications which require variable speed, the use of induction motor is limited as a result of low efficiency and high cost penalty associated with the existing control techniques. The speed of the motor can be changed by various methods such as changing poles, controlling voltage, connecting resistance in rotor circuit etc, but most efficient method is changing the supply frequency and voltage to the motor. The variable frequency drive (VFD) varies the frequency and hence varies the speed of the motor as per the requirements of the load. [1]

II. BRIEF LITERATURE SURVEY

Dennis P. Connors [6], illustrated various types of Variable frequency drives (V.F.D) with their limitations and described basic relationships among drive voltage, frequency, torque, speed of the motor along with harmonic effect. Thomas A. Lipo [7], summarized various stages of developments of VFD, which linked technological innovations in power components, like silicon controlled rectifier (SCR), gate turn off thyristor (GTO), insulated gate bipolar transistor (IGBT), Pulse width modulation (PWM) controlled. Paresh C. Sen [8], described the substitute of DC drive performance by AC frequency drive, as a result of sustained research work in area of power electronic components and micro-controller. S. Takiyar [9], Paper on Hybrid method for customized control of Induction Motor. A hybrid method using ladder logic diagram and PWM based VFD which controls Induction motors. This system has an adaptive control for flexible operation. The authors have compared speed torque performance and efficiency of PLC based and inverter based VFD.

III. OPERATING PRINCIPLE

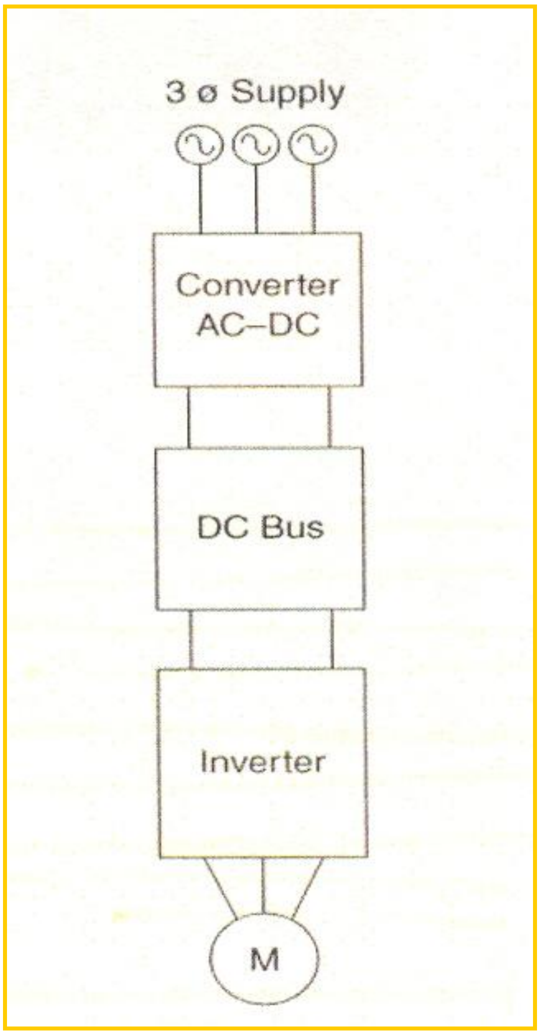

Fig.1: Block Digram of VFD [2]

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Muddasar Ali, PG. Scholar, Department of Electrical Engineering, Army Public College of Management & Sciences (APCOMS), Rawalpindi (UET) Taxila, Pakistan.

Khadija Jalal, PG. Scholar, Department of Electrical Engineering, Army Public College of Management & Sciences (APCOMS), Rawalpindi (UET) Taxila, Pakistan.

Dr. M. Ejaz Hassan, Associate Professor & Head, Department of Electrical Engineering, Army Public College of Management & Sciences (APCOMS), Rawalpindi (UET) Taxila, Pakistan.

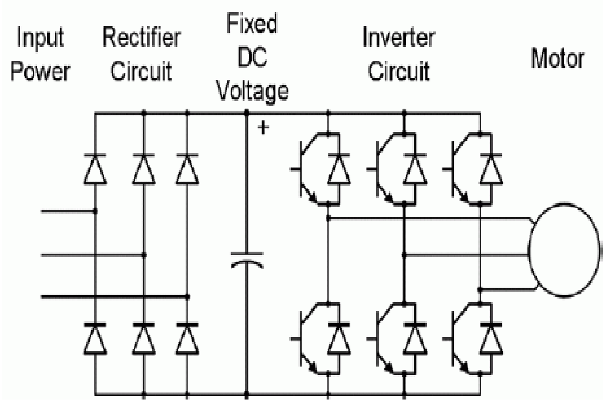

Fig.2: Power Conversion Unit for VFD [2]

The basic principle of VFD operation requires an understanding of the three basic sections: the Rectifier unit, DC Bus and the Inverter unit. The supply voltage is first passed through a Rectifier where it gets converted from AC to DC supply. The DC bus comprises a filter section where the harmonics generated during the AC to DC conversion are filtered out. The last section consists of an inverter section which comprises Gate Bipolar Transistors (IGBT) where the filtered DC supply is being converted into quasi-sinusoidal wave of AC supply which is supplied to the induction motor. The synchronous speed of an electric motor is dependent on the frequency, so by varying the frequency through VFD the speed of the motor can be controlled. [3]

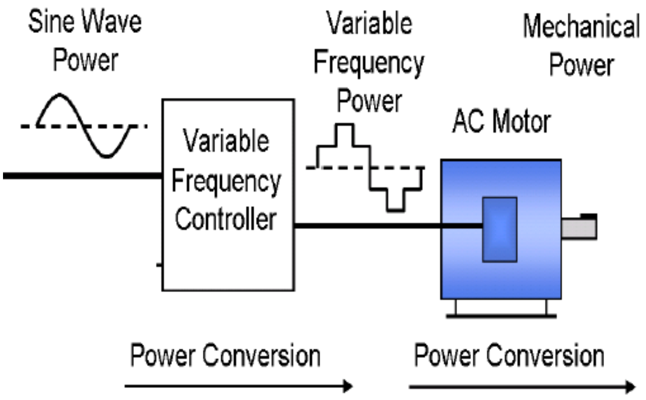

Fig.3: Variable Frequency Drive [3]

IV. PULSE WIDTH MODULATION TECHNIQUE

Pulse width modulation (PWM) inverter produces pulses of varying widths which are combined to build the required waveform PWM produces a current waveform that more closely matches the line source, which reduces undesired heating. PWM drive has almost constant power factor at all speeds which is close to unity. PWM units can also operate

Multiple motor on a single drive. Thus the carrier frequency is derived from the speed of the power device switch remains ON and OFF drive. It is also called switch frequency. The Higher the carrier frequency of the power line, the higher the resolution of the pulse width modulation. [4]

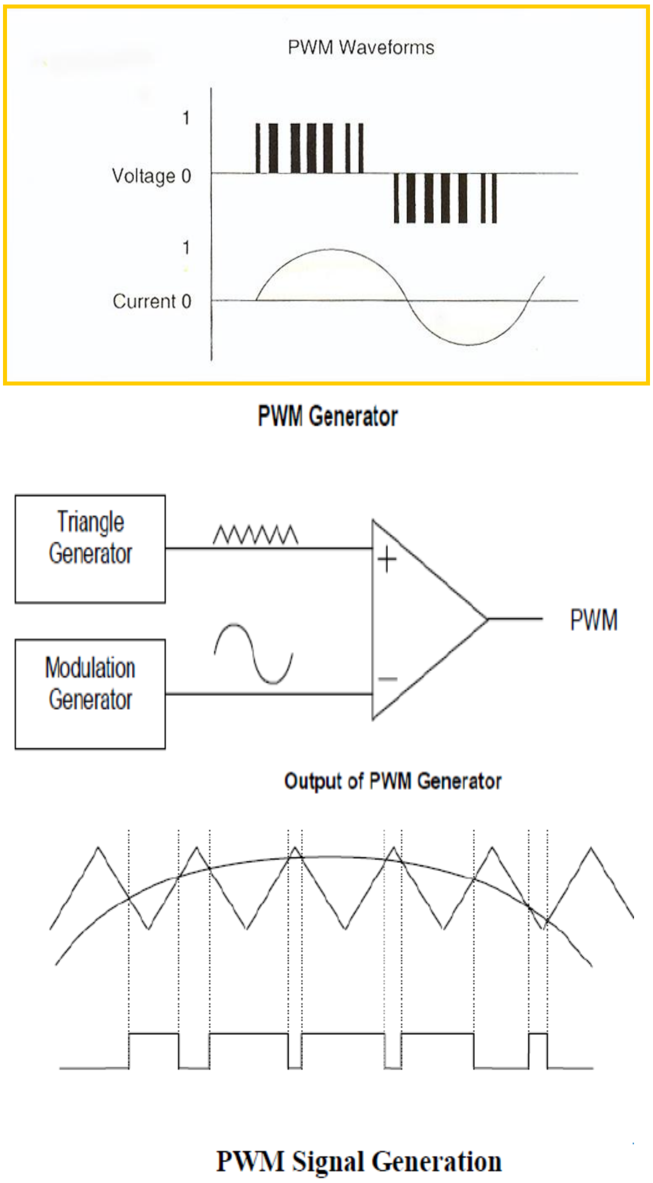

Fig.4: Generation of PWM Signal [4]

V.CONSTANT (V/F) RATIO OPERATION

All Variable Frequency Drives maintain the output voltage to frequency (V/f) ratio constant at all speeds for the reason that follows. The phase voltage V, frequency f and the magnetic flux Φ of the motor are related by the equation:

$$V = 4.444\, f\, N\Phi_m \quad \text{or} \quad V/f = 4.444 N\Phi_m$$

Where N = Number of stator turns per phase.

Φ_m = Magnetic flux.

If the same voltage is applied at the reduced frequency, the magnetic flux would increase and saturate the magnetic core, significantly distorting the motor performance. The magnetic saturation can be avoided by keeping the Φm constant. Moreover, the motor torque is the product of stator flux and rotor current. For maintaining the rated torque at all speeds the constant flux must be maintained at its rated value, which is basically done by keeping the voltage – to – frequency (V/f) ratio constant. That requires the lowering of the motor voltage in the same proportion as the frequency to avoid magnetic saturation due to high flux or lower than the rated torque due to low flux. [5]

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VI. SIMULINK MODEL FOR SPEED CONTROL OF AN INDUCTION MOTOR USING PULSE WIDTH MODULATION TECHNIQUE (PWM).

The Simulation is shown in Fig.5 with an inverter using Pulse Width Modulation technique. Frequency and amplitude of output voltage is varied by using PWM technique and these controlled voltage and frequency are used to control motor speed. We have used discrete 3-phase PWM generator, the discrete 3-phase PWM generator blocks generates pulses for carrier base PWM converters. The block is used to fire the IGBT of 2 level converters. Using a single bridge or two bridge connected in twin configuration vector its output of P1 or P2 either 6 pulses (2 level) or 12 pulses (3 level). Simulation Parameters are given in Table 1.

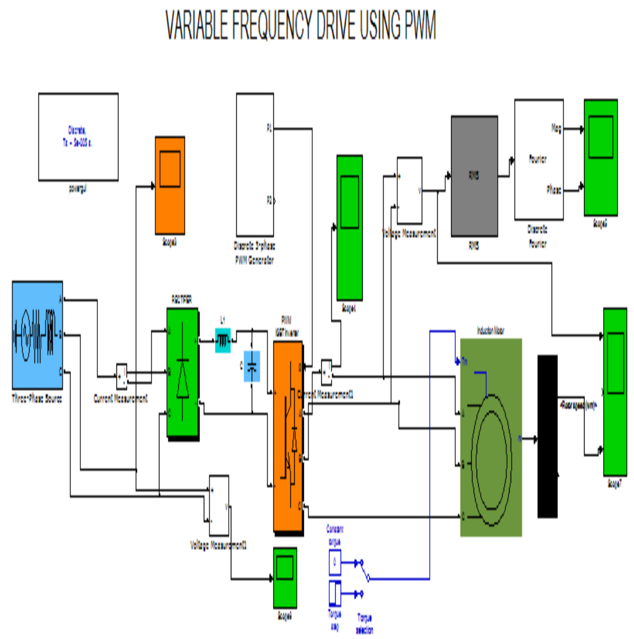

Fig.5: Matlab Simulink Model of VFD

Table 1. Simulation Parameters Carrier Frequency of PWM Generator f=1000Hz Modulation Index=1

S. No	Parameters	Values
1	Supply Voltage	380V
2	Supply Frequency	50Hz
3	Rotor Type	Squirrel Cage
4	Motor Rating	5.4 HP
5	Number of poles	4
6	Snubber resistance and capacitance	1e5 Ω, Inf
7	Inverter	IGBT TYPE
8	Rectifier	Bridge TYPE
9	Capacitance(dc link)	5000e-6 F
10	Inductance(dc link)	200e-6 H
11	Stator resistance and inductance	1.405Ω, 0.005839H
12	Rotor resistance and inductance	1.395Ω, 0.005839H
13	Mutual inductance	0.1722 Ω
14	Inertia	0.0131kg-$m2$
15	Friction factor	0.002985
16	Initial condition	1 0 0 0 0 0 0 0

VII. SIMULATION RESULTS

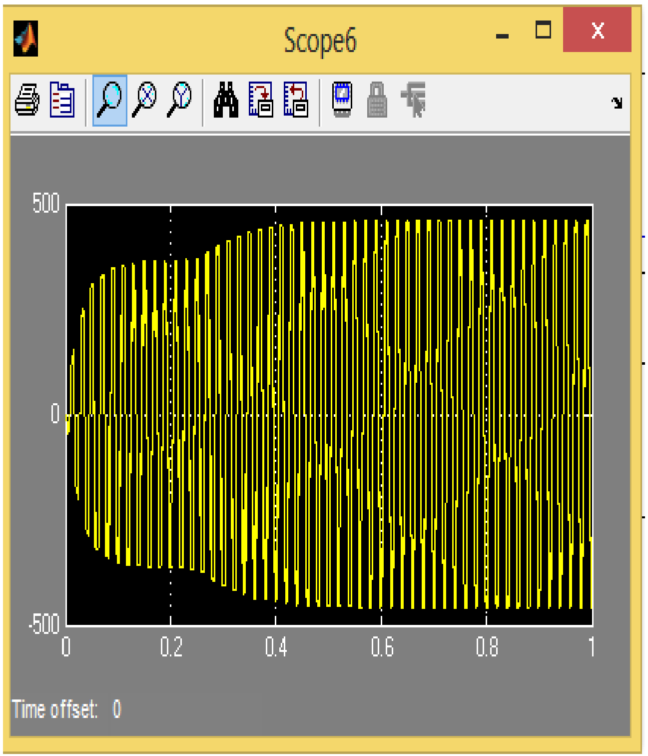

Fig.6: Input Voltage Waveform

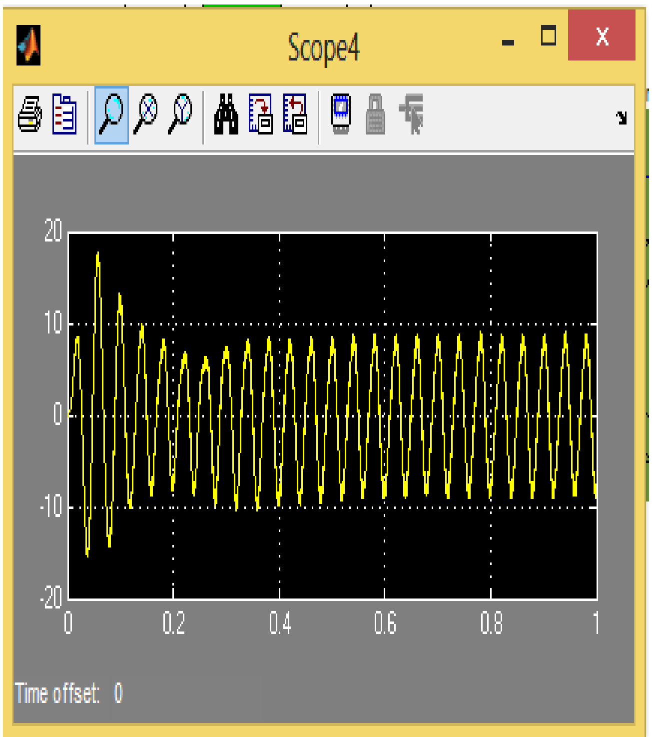

Fig.7: Output Current of Inverter Waveform

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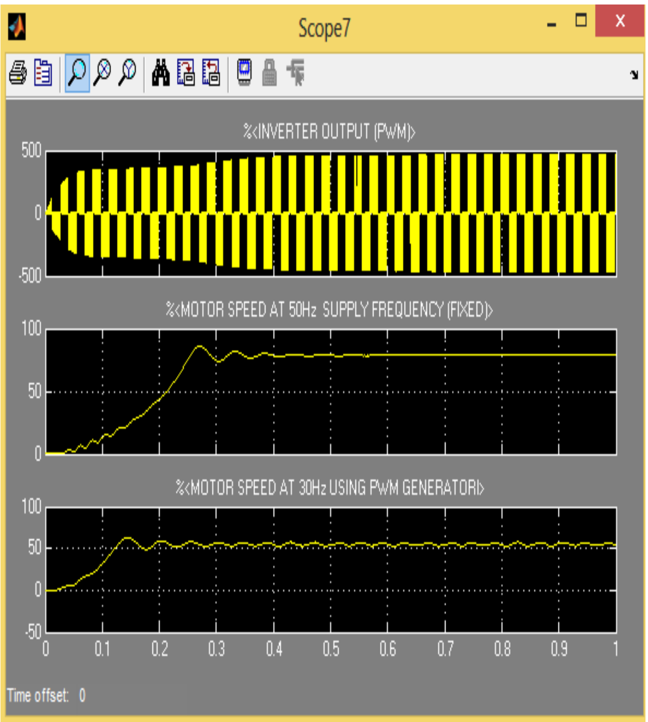

Fig.8: AT Frequency of PWM Generator (F=30Hz) Motor Speed Wm~ 50rpm

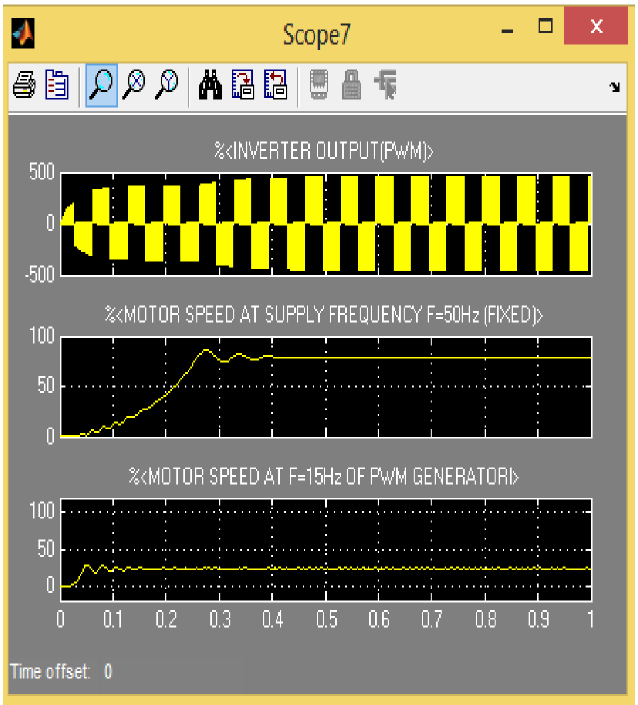

Fig.9: AT Frequency of PWM Generator (F=15Hz) Motor Speed Wm~ 20rpm

VIII. CONCLUSION

In this Paper variable frequency drives is used to control the speed of an induction motor based on PWM technique. The input supply frequency is fixed at 50Hz. The rotor speed of induction motor is varied by varying the PWM generator frequency of inverter at f=30 Hz and f=15Hz.It can be seen that the speed of the rotor is reduced by decreasing the frequency of PWM generator as shown in figure 8 and 9. After the study of variable frequency drive, now it becomes possible to control the speed of induction motor for variable speed applications.

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AUTHORS PROFILE

Muddasar Ali, has obtained BE degree in Electrical Engineering from Air University, Islamabad in 2015. Currently, he is PG-Scholar of Electrical Engineering at Army Public College of Management & Sciences (APCOMS), Rawalpindi (UET) Taxila, Pakistan. His research interest includes, Advanced power electronics, Electrical machine modeling, Power system stability analysis and Energy system Engineering.

Dr. M. Ejaz Hassan, has obtained PhD degree in Electrical Engineering from UET Peshawar. Currently, he is working as Associate Professor and Head of Electrical Engineering department at Army Public College of Management & Sciences (APCOMS), Rawalpindi (UET) Taxila, Pakistan. His research interest includes Modern control systems and Electrical power Engineering

Khadija Jalal, has obtained BE degree in Electrical Engineering from Air University, Islamabad in 2015. Currently, she is PG-Scholar & Lab Engineer of Electrical Engineering at Army Public College of Management & Sciences (APCOMS), Rawalpindi (UET) Taxila, Pakistan. Her research interest includes optimization techniques, Power generation and transmission systems.