Comparative study of Variable frequency drive to run an AC Induction motor using synchronized and unsynchronized PWM generator, with and without filter

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Abstract: **This comparative study has been performed to check the most efficient and smooth working of an AC induction motor by reducing the total harmonic distortion by using different methods in variable frequency drive. Hence the results are obtained using the simulation of various methods and observed the best technique for direct torque control (DTC) of the machine.**

This paper is presented based on the results obtained using MATLAB simulation software.

Index Terms **– PWM generator, Asynchronous machine.**

I. INTRODUCTION

Every waveform of voltage or current or flux are desired to be sinusoidal under ideal condition. Under practical conditions tend to become non-sinusoidal. A waveform becoming non-sinusoidal means along with the fundamental, harmonic component must be induced within the system. The harmonic information can be obtained by writing the Fourier series of non-sinusoidal periodic waveform.

AC motors are used for converting electrical energy to mechanical energy. They are used in various applications in different industries, factories and automobiles as locomotives. These motors need controlled power to control the speed and torque. Hence, we use variable frequency drive (VFD) [4] to have a direct torque control(DTC) over machines . Variable frequency drive consists of power electronic circuit combined with a controlling circuit which are used to vary the speed and torque of the machine [1]. In general,VFD converts DC to variable frequency AC or AC(fixed frequency) to AC(variable frequency).

This project has been done to show the comparative study of various methods to decrease total harmonic distortion (THD) [3]. We have seen that the total harmonic distortion has been reduced as we approach different methods. To verify our generated input to the machine, we have considered a 3-phase, 5.4Hp (4kW),400V,50Hz, 1430RPM asynchronous machine operated as a motor. By supplying the available DC input through the drive into the 3-phase asynchronous machine, we verify characteristics of Speed, Stator current, and Electromagnetic torque with respect to time at the motor [2].

II. METHODOLOGY

a. 3-phase, 2-Level variable frequency drive.
b. 3-phase, 3-Level variable frequency drive with unsynchronized mode of operation of PWM generator.
c. 3-phase, 3-Level variable frequency drive with synchronized mode of operation of PWM generator.

(a) 3-PHASE, 2-LEVEL VARIABLE FREQUENCY DRIVE.

Figure 1, shows the 3-phase, 2-Level variable frequency drive along with its output connected to the input of themotor. Here a 2-level PWM generator and a universal bridge as a part of a drive, convert available 400V DC to 3-phase 2-level AC. The input voltage to the motor is measured with the voltage measuring instrument. Parameters of PWM generator and universal bridge are mentioned in Table 1.

Table 1: Parameters of PWM generator and universal bridge.

Blocks	**Parameters**	**Value**
PWM generator	Generator type	Three-phase bridge (6 pulses)
	Mode of operation	Unsynchronized
	Frequency	27*50Hz
	Initial Phase	0 degrees
	Minimum and maximum values	[-1, 1]
	Sampling technique	Natural
	Internal generation of reference signal	Selected
	Modulation index	0.9
	Reference signal frequency	50Hz
	Reference signal phase	0 degrees
	Sample time	10e-6 s
Universal bridge	Number of bridge arms	3
	Power Electronic device	IGBT/Diodes

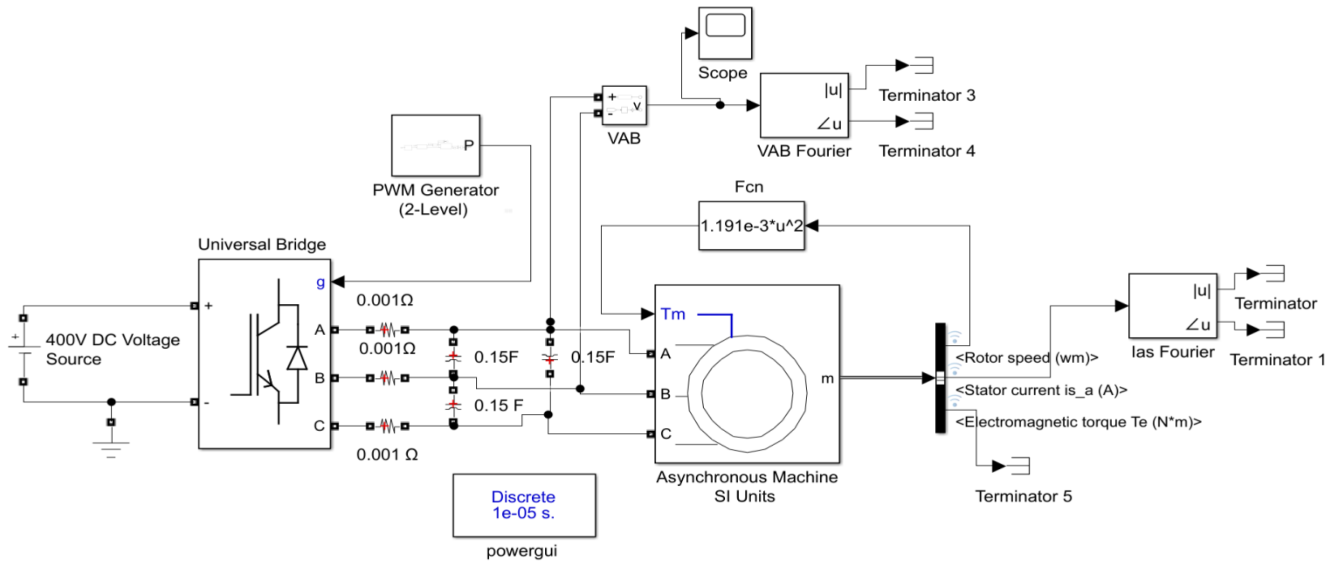

Figure 1: circuit diagram of 3-phase, 2-Level variable frequency drive.

Figure 2, shows characteristics of Speed, Stator current, and Electromagnetic torque with respect to time at the motor. The motor starts rotating and reaches its steady-state speed of 133rad/s (1270rpm) after 0.16s. At starting, the magnitude of the 50 Hz current reaches 41.5A peak (29A RMS) whereas its steady-state value is 17.5A (12.37A RMS).With the average torque value equal to 21Nm.

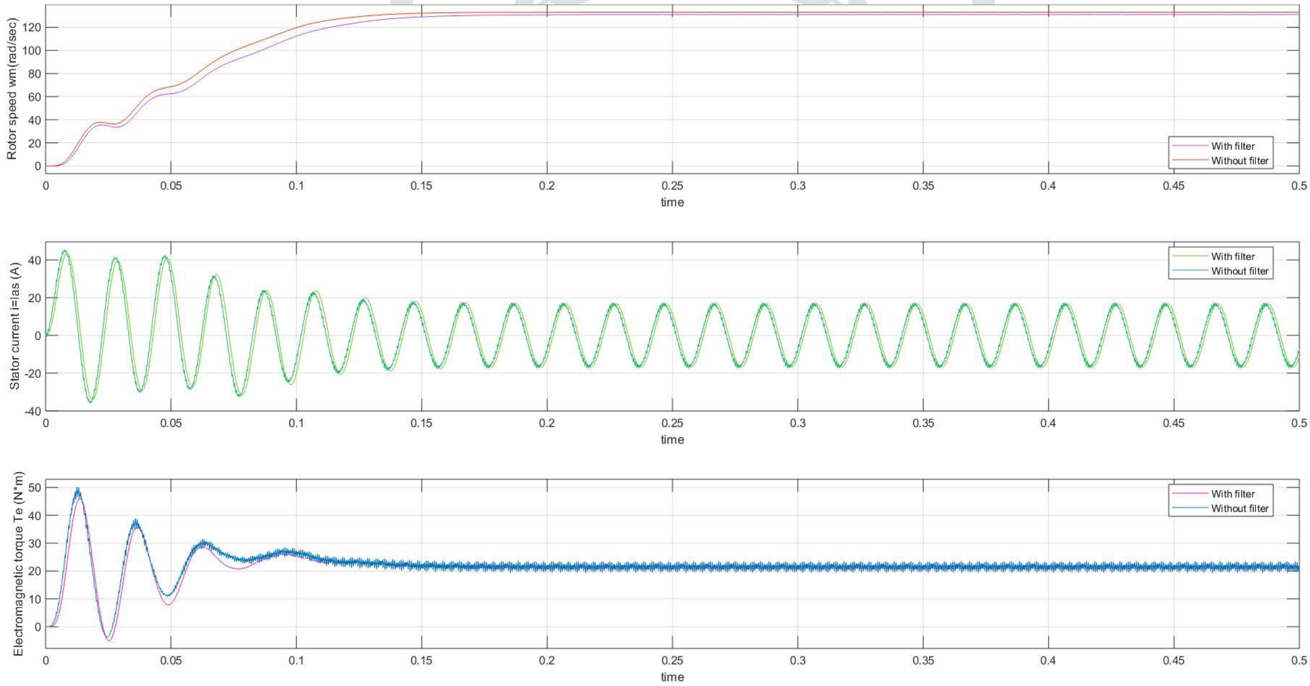

Figure 2: characteristics of Speed, Stator current, and Electromagnetic torque with respect to time of method (a) with and without filter.

Powergui FFT analysis tool is used to perform harmonic analysis, to obtain the fundamental component and THD of theV_{ab} voltage. Figure 3 is the spectrum window showing the fundamental component and THD of the V_{ab} voltage without filter. We can observe that theinverter voltage being 400V for modulation index equal to0.9.This signal being 2-level oscillates between 0 and +/-400V gives a THD magnitude of 79.87%. The highest harmonic of 30% occurs around the multiple of carrier frequency, at 25th harmonic (27-2) and 29th harmonic (27+2). Similarly, Fig.4 shows the same signal after adding filter, which gives the THD magnitude of 6.96%. FFT settings are shown in Table 2. In this tableexcept start time all the parameter values are same for all the remaining methods.

Table 2: FFT settings.

Parameters	Value
Start time (s)	0
Number of cycles	5
Fundamental frequency	50Hz
Max frequency	5000Hz
Max frequency for THD computation	Nyquist frequency

Display style	Bar (Related to fundamental)
Base value	1.0
Frequency axis	Harmonic order

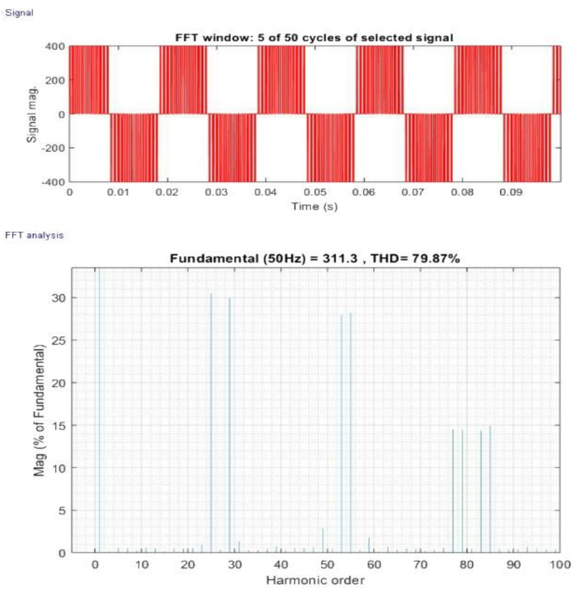

Figure 3: FFT analysis of 3-phase 2-level line voltage V_{ab} without filter.

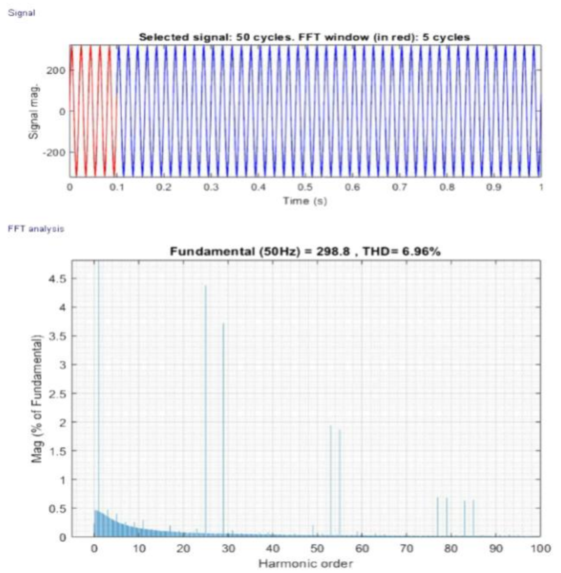

Figure 4: FFT analysis of 3-phase 2-level line voltage V_{ab} with filter.

(b) 3-PHASE, 3-LEVEL VARIABLE FREQUENCY DRIVE WITH UNSYNCHRONIZED MODE OF OPERATION OF PWM GENERATOR.

Figure 5, shows the 3-phase, 3-Level variable frequency drive along with its output connected to the inputof themotor. Here a 3-level PWM generator and a 3-level bridge as a part of a drive, convert available 400V DC and 200V DC to 3-phase 3-level AC with the circuit as shown in Fig.5. Rest of the circuit being same as Fig.1, parameters of 3-level PWM generator and 3-level bridge is mentioned in table 3.

Table 3: Parameters of 3-level PWM generator and three-level bridge.

Blocks	**Parameters**	**Value**
PWM generator	Generator type	Three-phase bridge (12 pulses)
	Mode of operation	Unsynchronized
	Frequency	27*50Hz
	Internal generation of reference signal	Selected
	Modulation index	0.9
	Output voltage frequency	50Hz
	Outputvoltage phase	0 degrees
	Sample time	10e-6 s
Three-level bridge	Number of bridge arms	3
	Power Electronic device	IGBT/Diodes

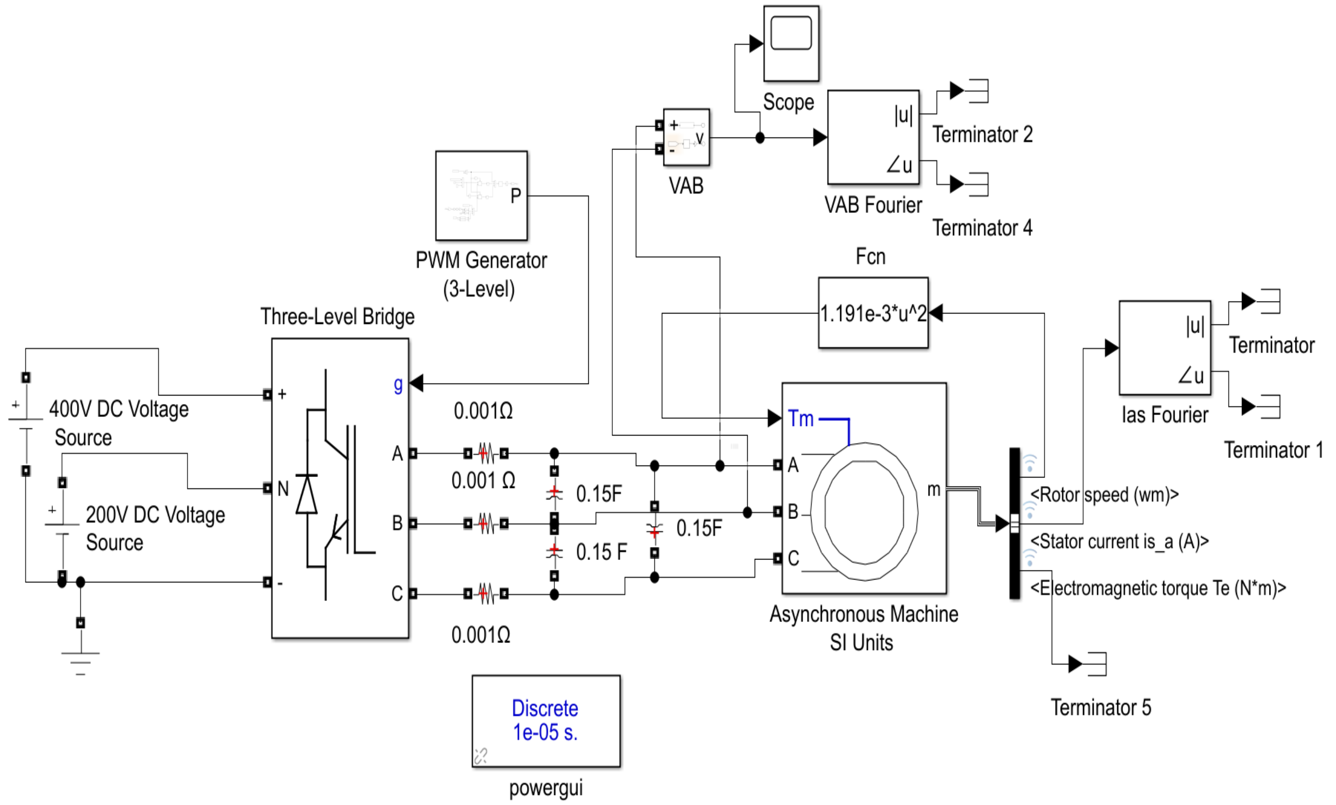

Figure 5: Three-Phase, Three-Level variable frequency drive with unsynchronized mode of operation of PWMgenerator.

Comparison of Fig.6with all the methods is carried out in Table 5 and harmonic analysis for input voltage signal is been carried out and compared with all the methods in Table6.

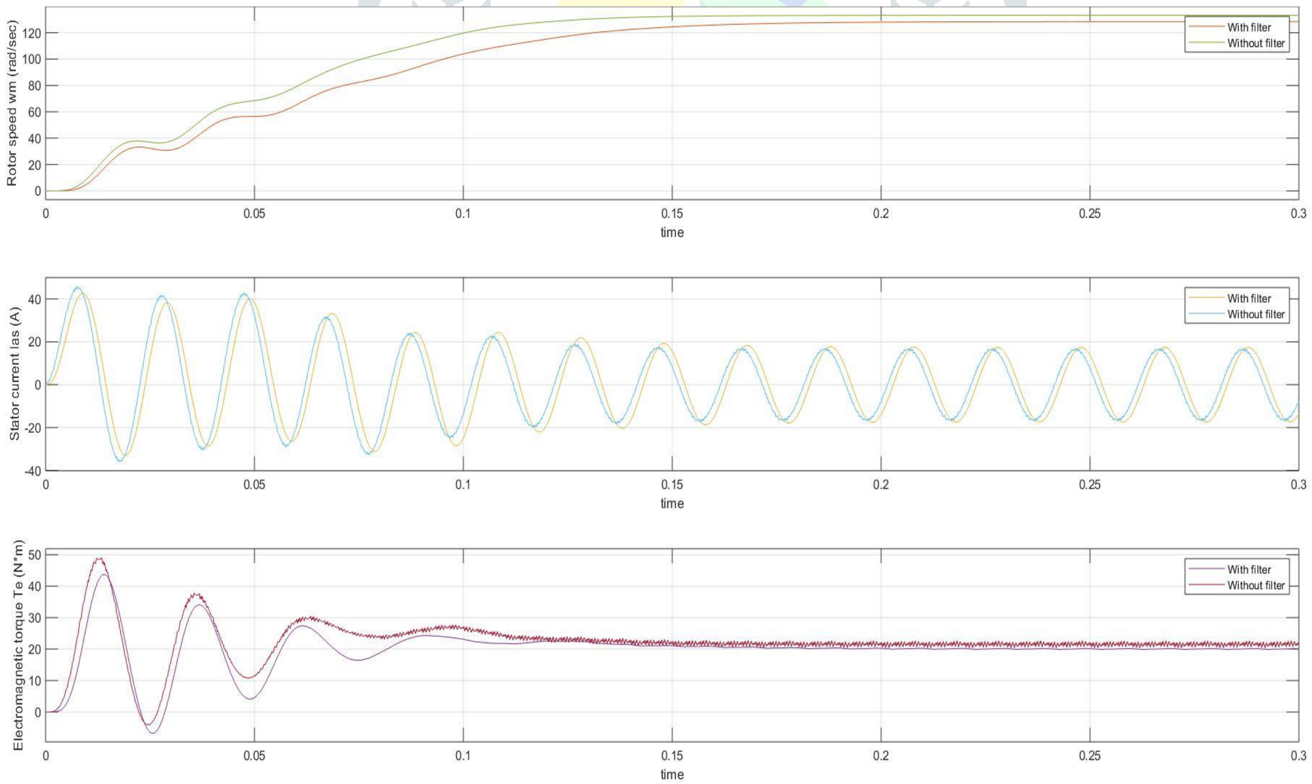

Figure 6: Characteristics of rotor speed, stator current, and electromagnetic torque of method (b) with and without filter.

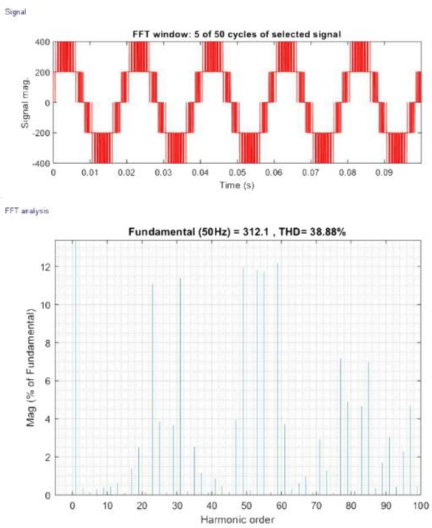

Figure 7: FFT analysis of unsynchronized 3-phase 3-level line voltage V_{ab} without filter.

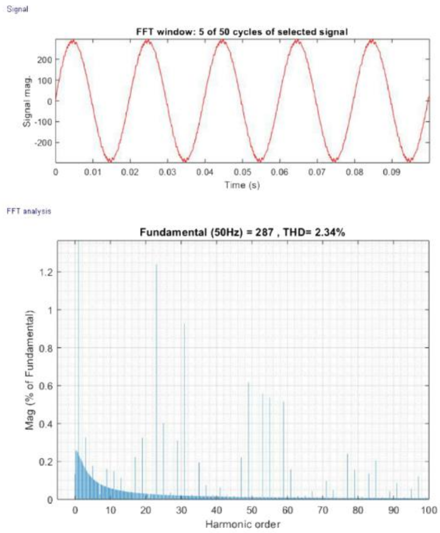

Figure 8: FFT analysis of unsynchronized 3-phase 3-level line voltage V_{ab} with filter.

(c) 3-PHASE, 3-LEVEL VARIABLE FREQUENCY DRIVE WITH SYNCHRONIZED MODE OF OPERATION OF PWM GENERATOR.

Figure 6, shows the 3-phase, 3-Level variable frequency drive along with its output connected to the input of themotor.Here, PWM generated under the synchronous mode of operation, expect the carrier signal (Uref) synchronized to an external reference signal (wt). Rest of the circuit being same as Fig.5, parameters of 3-level PWM generator, 3-phase programmable generator and sine wave blocksare mentioned in table 4.

Table 4: Parameters of 3-level PWM generator, 3-phase programmable generator and stair generator.

Blocks	**Parameters**	**Value**
PWM generator	Generator type	Three-phase bridge (12 pulses)
	Mode of operation	synchronized
	Switching ratio (carrier frequency / output frequency)	10,000Hz
	Sample time	10e-6 s
Three-phase programmable generator	Positive-sequence [Amplitude, Phase (degrees), Freq. (Hz)]	[1,0,50]
	Time variation of	Amplitude
	Type of variation	Modulation
	Sample time	10e-6 s
Sine	Amplitude	1
	Frequency	2*pi*50
	Phase	0
	Sample time	0 s

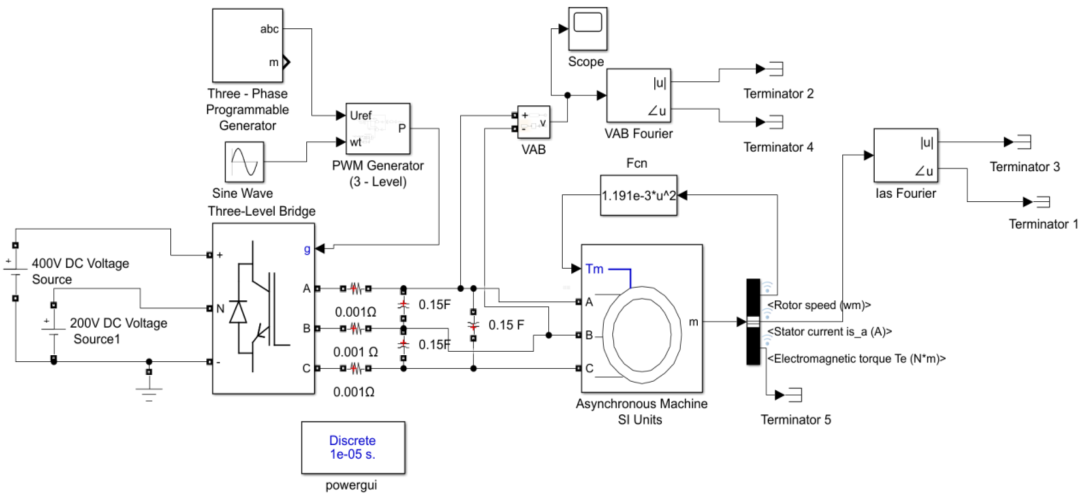

Figure 9: Three-Phase, Three-Level variable frequency drive with synchronized mode of operation of PWM generator.

Comparison of Fig.10 all the methods is carried out in Table 5 and harmonic analysis for input voltage signal is been carried out and compared with all the methods in Table 6.

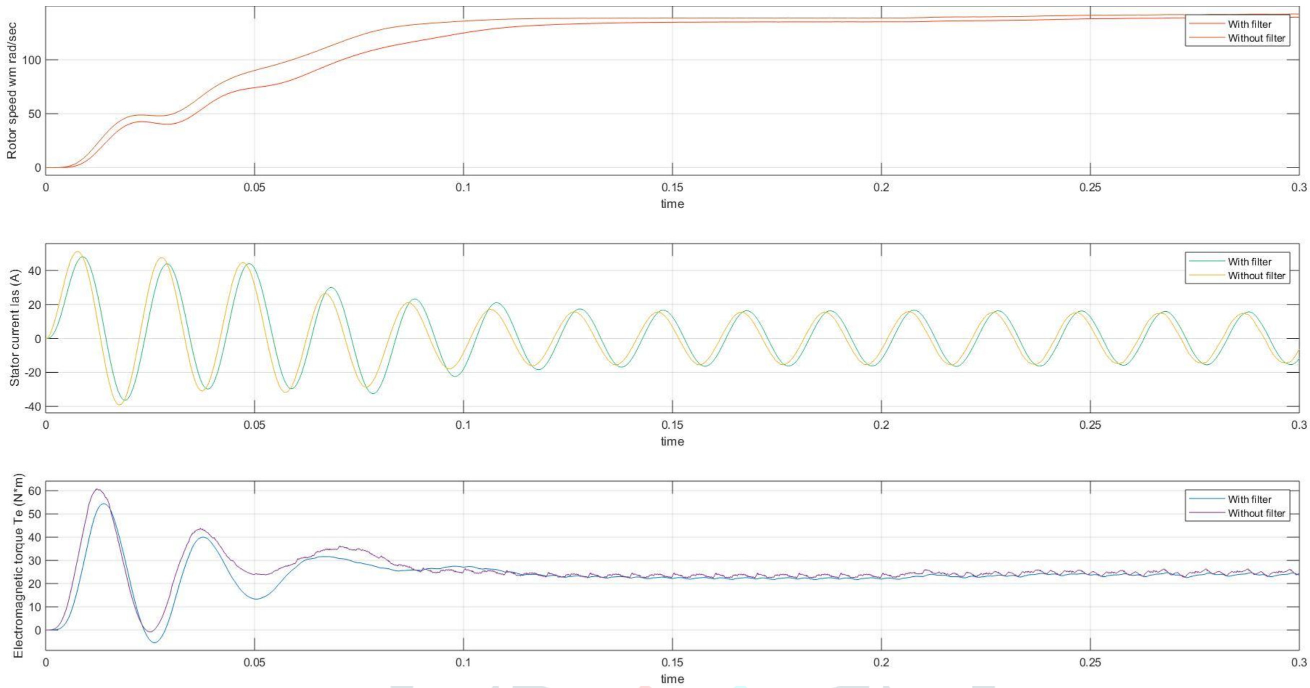

Figure 10: Characteristics of rotor speed, stator current, and electromagnetic torque of method (c) with and without filter.

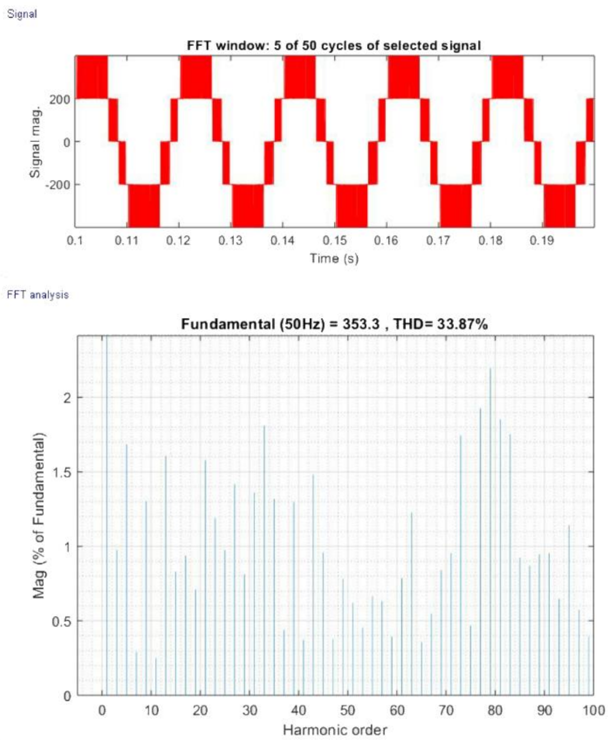

Figure 11: FFT analysis of synchronized 3-phase 3-levelline voltage V_{ab} without filter.

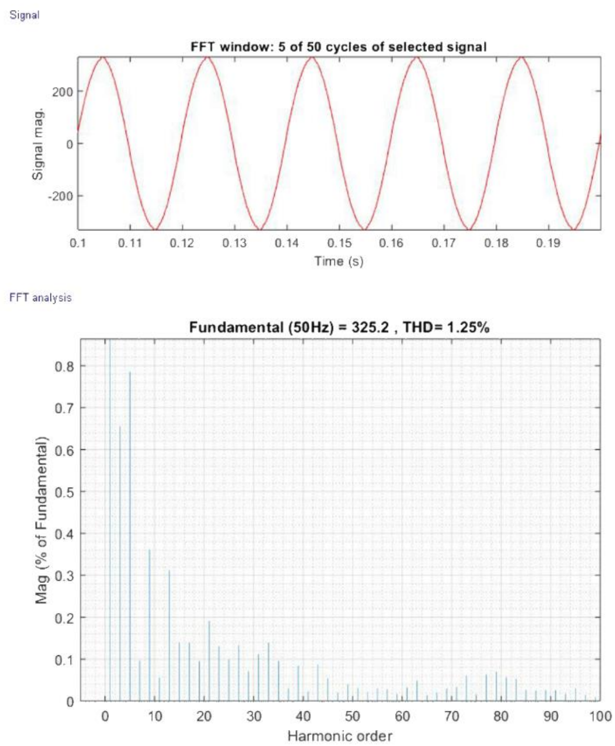

Figure 12: FFT analysis ofsynchronized 3-phase 3-level line voltage V_{ab} with filter.

III. SPEED CURVE

To obtain variable speed at the output of the motor, the fundamental frequency at the PWM generator is changed in the steps of 5 from 40Hz to 50Hz. The variations in the rotor speed of asynchronous motor can be observed from the fig.13. We can also observe that, as the frequency increases the motor speed increases.

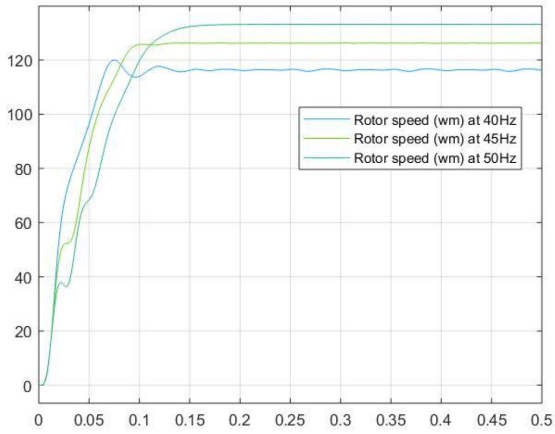

Figure 13: Rotor speed at various frequencies.

IV. RESULTS AND DISCUSSION

From table 5, we can observe that three level synchronized method provides better torque and speed characteristics with lesser settling time. With torque and speed value being more for the same input the efficiency of this design is high compared to other two methods.

Table 5: Comparison ofcharacteristics of rotor speed, stator current, and electromagnetic torque between all three methods without filter.

Methods	Rotor speed (rad/sec)	Stator current (RMS)	Average Te(Nm)	Settling timein seconds.
Two level	133	12.37A	21	0.16
Three level unsynchronized	133	11.80A	22	0.17
Three level synchronized	138.8	11.52A	23.5	0.12

The filter that is used contains a series resistor (0.001Ω) in all 3 lines and a capacitor (.15F) in parallel between every line to line. By using the same filter designed in all three methods the THD obtained are tabulated in the table 6. From table 6 we can observe that three level synchronized drive method generates less harmonics in the generated AC voltage signal.

Table 6: Comparison of THD of voltage signal generatedfrom all three methods.

Methods	THD without filter	THD with filter
Two level	79.87%	6.96%
Three level unsynchronized	38.88%	2.34%
Three level synchronized	33.87%	1.25%

V. CONCLUSION

The comparative study has been carried out with the output obtained from the MATLAB simulation results andcomparing the data from the simulation results we found out theFFT analysis of synchronized 3-phase 3-level with filter,one can achieve better results in the design of variable frequency drive.

VI. REFERENCES

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