

THD Analysis of Five Phase Inverter for Different Conduction Modes

^[1]ShivaniKhandagare, ^[2]Shivani Shende, ^[3]TejaswiniKirpane

^[1], ^[2] Shri Ramdeobaba College of Engineering and Management

^[1]shivanihandagare7@gmail.com, ^[2]shende.shivani2104@gmail.com ^[3]kirpanetg@rknc.edu

Abstract—Multi-phase supply has several advantages over three phase supply, it shows large contribution in motor concern by reducing torque pulsations, higher torque density, greater fault tolerance meanwhile it also reduces the required rating per inverter leg (simpler and more power conditioning equipment). To reduce the harmonics for smooth operation and to reduce heating in the equipment, the motor/load has to be supplied with multiphase supply greater than a three phase supply. Therefore five phase supply is preferred. This paper proposes a comparison of five phase supply fed inverter connected to star and delta connected load. The inverter drive is simulated for variable conduction periods i.e. from 72° to 180°. The FFT analysis is carried out for respective conduction periods.

Index Terms—Multi-phase supply, 5-phase inverter, 180° conduction period, 72° conduction period, FFT(Fast Fourier transform) analysis

I. INTRODUCTION

Since the standard power supply is three phase therefore conventional three phase drives are commonly used. Multiphase machines are not so popular because of the fact that the supply for multiphase machines are not available. Whereas multiphase drives provides more advantages as compared to conventional drives. The multiphase or polyphase drives were introduced due to upgradation in power electronics. As the number of phases increases the advantages gets amplified. Electric machines having more than three phases provides more benefit as compared to conventional machines-

- a) Reduced torque pulsation
- b) Greater fault intolerance.
- c) Higher reliability
- d) Reduction in the required rating per inverter leg.
- e) Reduced per phase current.
- f) Lowering the dc-link current harmonics.

Multiphase systems are applicable in areas where high power and reliability is demanded such as Electric/hybrid vehicles, aerospace application, submarine propulsion, mining application, military vesselPropulsion. Multiphase machines are not so popular because of the fact that the supply for multiphase machines are not available. In power system harmonics are the main reason foroverheating,system failure,distorted wave shape,misfiring,poor power factor and many other problems. The several notable problems are due to harmonics in all types of inverter. An inverter converts input DC to output AC at required output current, voltage and frequency. In this paper simulation of five phase PWM inverter circuit using Simulink /MATLAB for both star connected and delta connected loads at different conduction period is presented and total harmonic distortion (THD) of current is compared. To achieve low THD of output current, the conduction period is modified from 36° to 180°.

1.1 Fivephaseinverter

Three phase system with the application of power electronics devices in high power drive system leads to many

complications like harmonics and less fault tolerant capability,the multiphase system came into existence. The multiphase supply system is previously unattainable therefore inverter is created to supply multiphase load.

The five phase voltage source inverter circuit for delta connected five phase load and star connected five phase load is shown in Fig.1. The circuit consist of five legs for five phases. Each leg consists of two IGBTs.To avoid short circuit across the dc link both the switches (S1 and S6, S3 and S8, S5 and S10, S7 and S2 or S9 and S4) of same leg should not be turned ON. Fig.1 shows the five phase voltage source inverter and the phase difference of five phase inverter is calculated by-

$$Phase-shift = \frac{360}{n} = \frac{360}{5} = 72$$

Where, n = number of phases

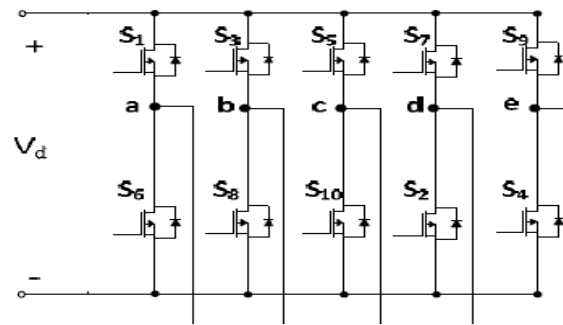


Fig.1 Five phase inverter

1.2 SIMULINK model of five phase inverter for star and delta connected load

Fig.1(a) and Fig.1(b) shows the MATLAB circuit of five phase voltage source inverter for delta and star connected load respectively. Load connected is highly inductive. The parameters that are considered in simulation are shown in Table 1-

Table 1: Parameters considered for simulation purpose

Parameters	Values
DC Source	400 V
Resistance	8 Ω
Inductance	0.25 H

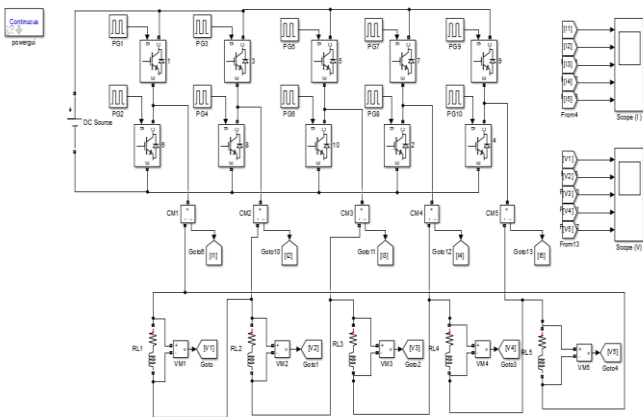


Fig.1(a) 5-ph inverter for delta connected load

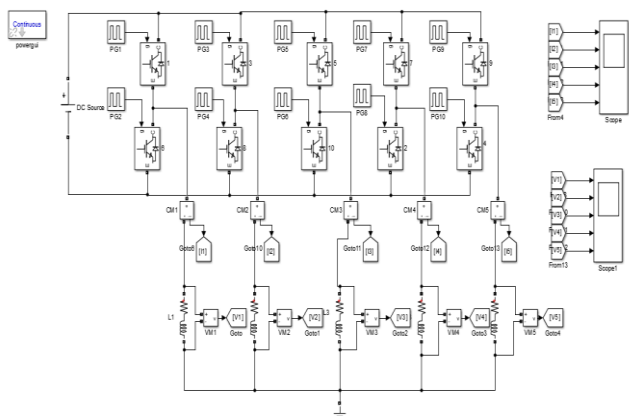


Fig.1(b) 5-ph inverter for star connected load

1.3 Modes of Conduction

A. 36 degree Mode of Conduction

Only one switch will remain ON for 36 degree mode of conduction. Each switch conducts for 36 degree and its switching sequence is given in Table 2. The THD of output current for delta and star connected five phase load is as follows-

Table 2: Switching Modes for 36 degree conduction

	36	72	108	144	180	216	252	288	324	360
S1	ON									
S2		ON								
S3			ON							
S4				ON						
S5					ON					
S6						ON				
S7							ON			
S8								ON		
S9									ON	
S10										ON

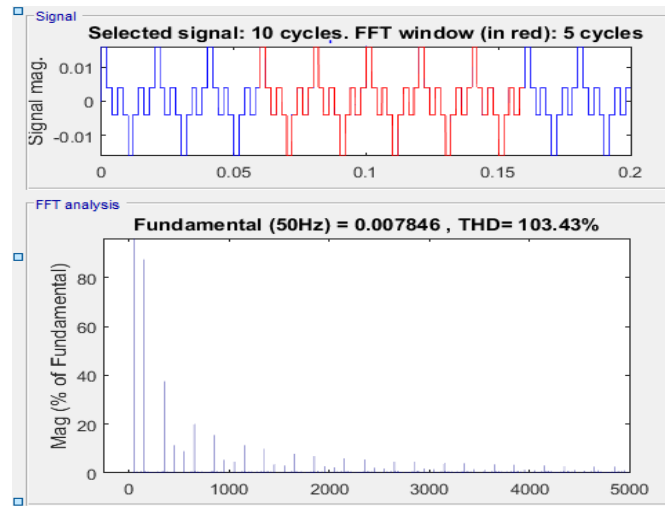


Fig.2(a)Current THD for delta connected load

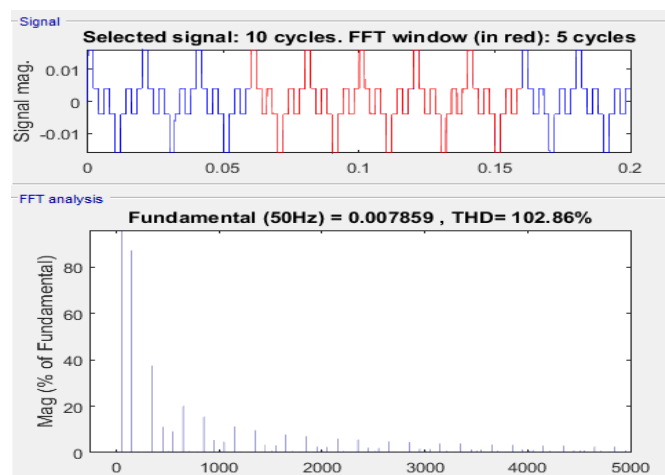


Fig.2(b) Current THD for star connected load

B. 72 degree Mode of Conduction

Only two switches will remain ON for 72 degree mode of conduction. Each switch conducts for 72 degree and its switching sequence is given in Table 2. The THD of output current for delta and star connected five phase load is as follows-

Table -3: Switching Modes for 72 degree conduction

	36	72	108	144	180	216	252	288	324	360
S1	ON	ON								
S2		ON	ON							
S3			ON	ON						
S4				ON	ON					
S5					ON	ON				
S6						ON	ON			
S7							ON	ON		
S8								ON	ON	
S9									ON	ON
S10	ON									ON

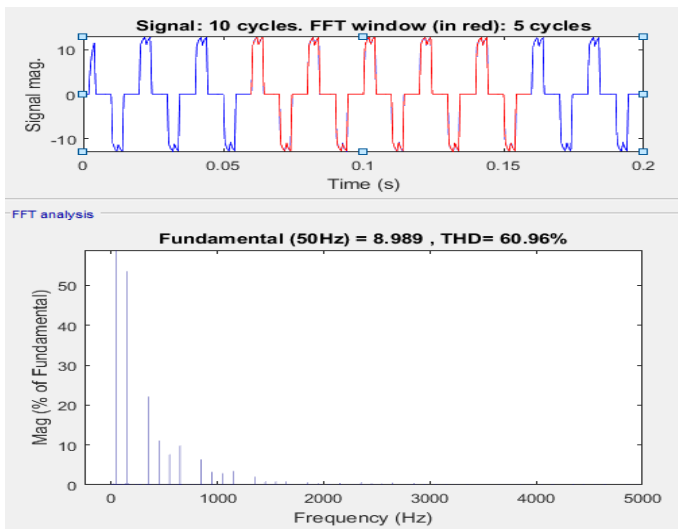


Fig.3(a) Current THD for delta connected load

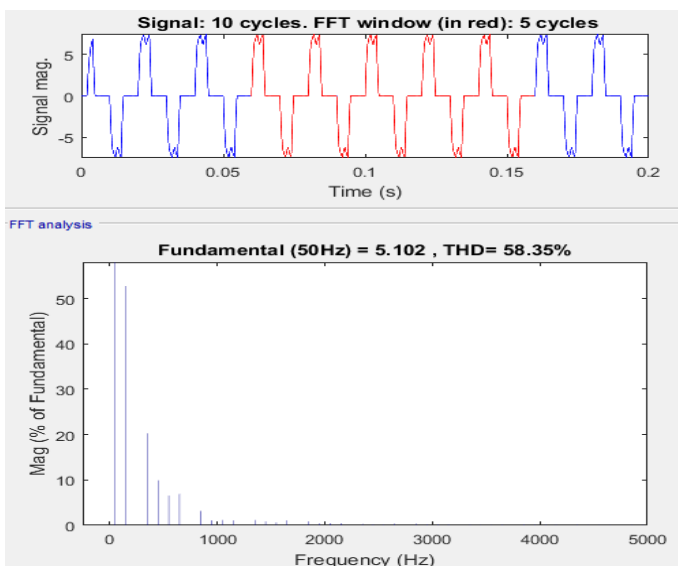


Fig.3(b) Current THD for star connected load

C. 108 degree Mode of Conduction

Only three switches will remain ON for 108 degree mode of conduction. Each switch conducts for 108 degree and its switching sequence is given in Table 4. The THD of output current for delta and star connected five phase load is as follows-

Table -4: Switching Modes for 108 degree conduction

	36	72	108	144	180	216	252	288	324	360
S1	ON	ON	ON	ON						
S2		ON	ON	ON	ON					
S3			ON	ON	ON	ON				
S4				ON	ON	ON	ON			
S5					ON	ON	ON	ON		
S6						ON	ON	ON	ON	
S7							ON	ON	ON	ON
S8	ON							ON	ON	ON
S9	ON	ON							ON	ON
S10	ON	ON	ON							ON

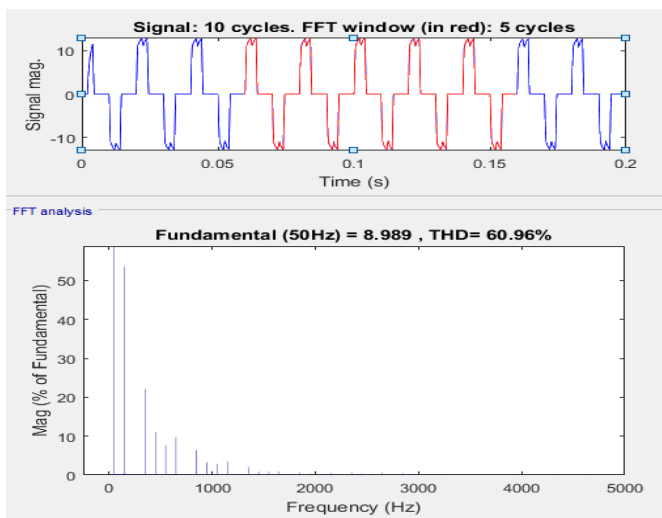


Fig.4(a) Current THD for delta connected load

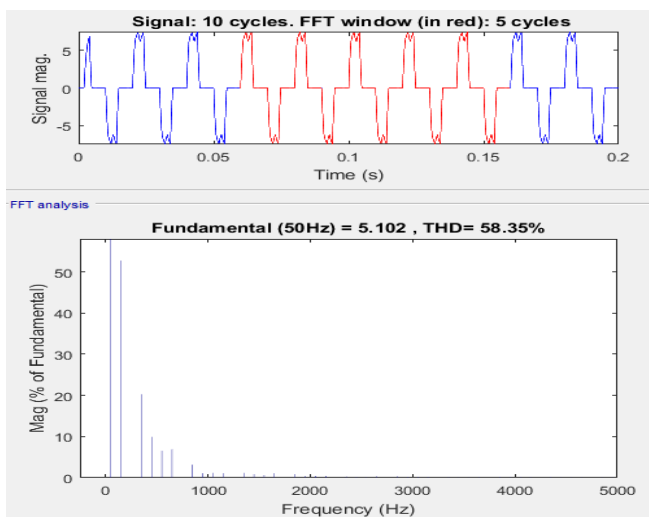


Fig.4(b) Current THD for star connected load

E. 180 degree Mode of Conduction

Only five switches will remain ON for 180 degree mode of conduction. Each switch conducts for 180 degree and it's switching sequence is given in Table 5. The THD of output current for delta and star connected five phase load is as follows-

Table -5: Switching Modes for 180 degree conduction

	36	72	108	144	180	216	252	288	324	360
S1	ON	ON	ON	ON	ON					
S2		ON	ON	ON	ON	ON				
S3			ON	ON	ON	ON	ON			

S4				ON	ON	ON	ON	ON		
S5					ON	ON	ON	ON	ON	
S6						ON	ON	ON	ON	ON
S7	ON						ON	ON	ON	ON
S8	ON	ON						ON	ON	ON
S9	ON	ON	ON						ON	ON
S10	ON	ON	ON	ON						ON

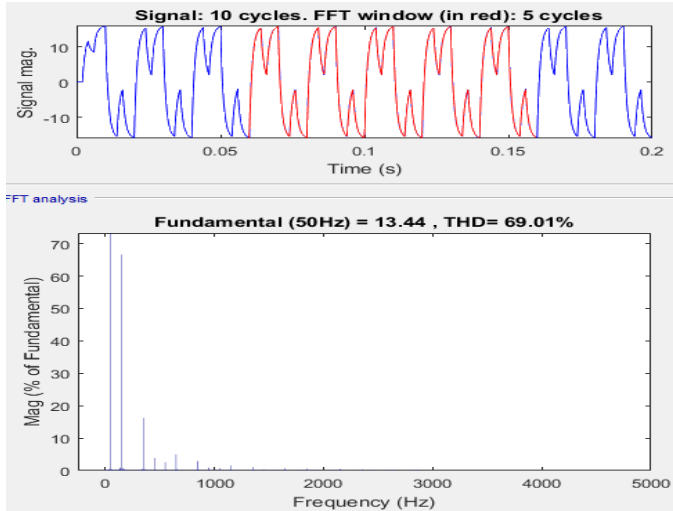


Fig.5(a) Current THD for delta connected load

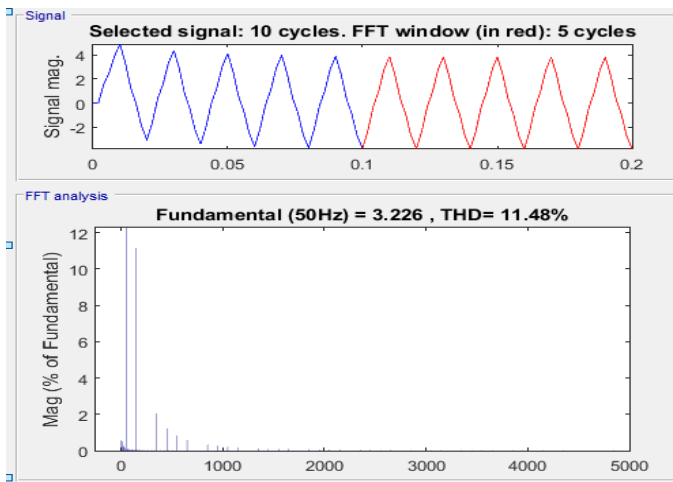


Fig.5(b) Current THD for star connected load

II. RESULTS AND DISCUSSION

The above results has been obtained for star connected load and delta connected load and tabulated below. It can be concluded that 144 degree mode of conduction for star connected load and 108 degree mode of conduction for delta are best mode of conduction to operate five phase inverter. Overall for five phase inverter with star connected load the THD of current is less as compared to delta connected five phase load. It is also seen that the 5th harmonic is almost negligible for delta connected five phase load.

Table -6: Results

Five phase inverter		THD in current	
S.no	Conduction period	Delta connected load	Star connected load
1	36	103.43	102.86
2	72	60.69	58.35
3	108	46.43	14.29

4	144	60.94	11.46
5	180	69.01	11.48

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