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Avinash Konkani
Rabindranath Bera
Samrat Paul
Editors

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Preface

Advances in Systems, Control and Automation is a collection of research articles and critical review articles presented in the International Conference on 'Emerging Trends and Advances in Electrical Engineering and Renewable Energy ETAEERE-2016,' organized by the Department of Electrical and Electronics Engineering (EEE) of Sikkim Manipal Institute of Technology (SMIT), Majhitar, Sikkim, India, during December 17–18, 2016. This was a very unique conference which combined renewable energy, electronics, computing, communication, systems, controls and automations under one roof. Moreover, it is a matter of honor for SMIT to learn that Springer was associated with ETAEERE-2016 as a major publication sponsor for the event. The proceedings of this conference come out with four different book volumes titled under Lecture Notes in Electrical Engineering (LNEE). The chapters cover the problems of multivariable control systems and provide the necessary background for performing research in the fields of control and automation. Aimed at helping readers understand the classical and modern design of different intelligent automated systems, this book presents coverage on the control of linear and nonlinear systems, intelligent systems, stochastic control, knowledge-based systems applications, fault diagnosis and tolerant control, real-time control applications, etc.

Eminent speakers like former Vice-Chancellor Prof. A Chakrabarti of Jadavpur University; Prof. A Rajaraman of IIT Chennai; Prof. Gyoo-Shee Chae of Baekshok University, South Korea; Prof. Avinash Konkani of University of Virginia, USA; Prof. Kamani KK (the global economic advisor of Karnataka); Prof. Manjesh of Bangalore University and Dr. Amitanshu Patnaik of DRDO Delhi shared their knowledge and experience. The conference attended and presented by participants from institutes such as IISc; IITs; NITs; NEHU; BIT; VIT; MIT Manipal; IIEST Kolkata and abroad deliberated on their research works. In addition the paper presentations were accompanied by six keynote addresses from leading academic and industry researchers around the globe. The paper presentations took place in 3 different tracks with 18 parallel sessions. Through the platform of ETAEERE-2016, we got the opportunity to promote the national campaign "Make In India."

The review committee has done an excellent job in reviewing the articles and approving the high quality research articles to be published in the conference proceedings. The editors are thankful to all of the faculty and students of these various committees for their dedication in making this a very successful conference and also to the editing and printing support staff of Springer for making the compilation possible. We sincerely hope that this volume will inspire researchers.

Majhitar, Sikkim, India

Karma Sonam Sherpa
Akash Kumar Bhoi
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Evaluation of Harmonics and THD in Five-Phase Inverter Constructed with High-Pass Filter by MATLAB Simulation

Manjesh, A.S. Ananda, Akash Kumar Bhoi and K.S. Sherpa

Abstract This chapter proposes and evaluates the feasible method to minimize the harmonic and its distortion. Many modern power systems incorporate different techniques to eradicate the harmonics, and filters are widespread methods used all over the world. Multi/polyphase power systems are trending because of improved performance of the system by their inherent advantages over traditional single and three-phase techniques [1]. The five-phase inverter is designed and studied with low-pass LC filter to evaluate and eradicate the behavior of harmonics in the five-phase inverter. Harmonics and THD comparison of the five-phase normal configuration with high-pass filter configuration are analyzed practically, and the results are presented in this chapter.

Keywords Five phase · Harmonics · Inverter · THD · Filters
High-pass filter

1 Introduction

Power quality improvement has been the motto for many researchers while designing the power systems. Higher phase order (HPO) systems have gained the attention in worldwide, and it is the specially designed power system which is better than the active

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three-phase power electronic scheme. Polyphase power electronic system has broad applications in industries and aircraft applications because of its high torque and low maintenance. Induction motor efficiency deteriorates and causes voltage imbalance in the windings of the induction motor which in turn generates d*v*/d*t* and ripple voltages at converter and inverter output power electronic systems. Multi/poly phase system is implemented in the applications of marines, powered vehicles (PVs) and hybrid powered vehicles (HPVs), aviation, traction, and very high-voltage and current etc. Polyphase power system has many advantages such as current reduction, reliable during its fault operations, and also ripple current reduction at the output of the converter system.

Many methods are reported in the prior research study for the injection of harmonics, and the one among them is nonlinear load in the inverter. Eradication of harmonics is considered as top priority in power quality improvement. Harmonics appear at resonance in any power systems, both in parallel and in series forms. Parallel resonance will effect in the amplification of the output line voltage distortions and series resonance will effect in obnoxious maximum harmonic load current. Nonlinear loads such as power switches in the inverter switching ON/OFF at high speed will generate harmonics and EMIs. These harmonics are superimposed on the fundamental pure sine wave, cause adverse effect on the power system performance by degrading the quality of the fundamental sine wave.

Power quality is optimized by suppressing the harmonics and to remove from the power electronic system the harmonics filter technique is feasible and also effective in power systems [12]. Passive and active are the two types of filters that can remove the harmonics and THD. In the five-phase systems, present harmonic orders are 3, 7, 9, 11, 13, 17, etc., and fifth and every multiple of fifth harmonic order are absent. The third harmonic order is the leading harmonic order which degrades the performance. To remove the third harmonic order, a high-pass filter is connected at the load stage of the inverter.

2 High-Pass Filter

There are three types of high-pass filter such as first order, second order, and third order. In the first order, capacitor and resistor are used and the power losses are more due to the presence of resistor. The second order is preferred by many designers to remove the higher-order harmonics. The second-order high-pass filter includes inductor, capacitor, and resistor, and a low resistor value leads to low power dissipation. High-pass filter is designed to remove the third harmonic order. The filter is designed to 15 Hz, and the capacitor (C), inductor (L), and resistor (R) are calculated as follows:

$$Q = R/(L2\pi f\mathrm{r})$$

where

$$Q = \text{quality factor}$$
$$f_r = \text{resonant frequency}.$$

3 Five-Phase Inverter

Inverter is constructed using ten power switches S_1–S_{10}, and MOSFET or IGBT can be used as switches. Gating signals are programmed by pulse generators and connected to the input gate of the IGBT's as shown in Fig. 1. All the ten switches are turned ON for the conduction period of 180° mode and having 72° out of phase with each other. Ten switching modes are programmed using pulse generator as depicted in Fig. 2. At Mode-1, switches $S_1S_3S_5S_7S_9$ will conduct; similarly, at Mode-2, $S_6S_8S_{10}S_2S_4$ will conduct.

Five-phase inverter drive is constructed with high-pass filter to eliminate the harmonics as shown in Fig. 2.

The calculated values of inductors L_1–L_5, capacitors C_1–C_5, and resistors R_1–R_5 in high-pass filter are shown in Table 1.

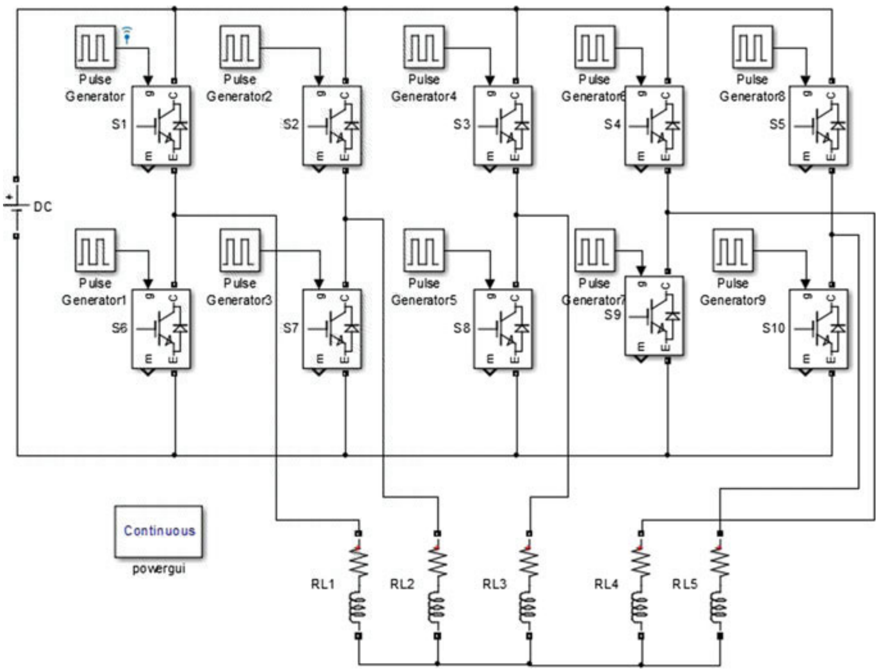

Fig. 1 5-phase inverter drive with RL load

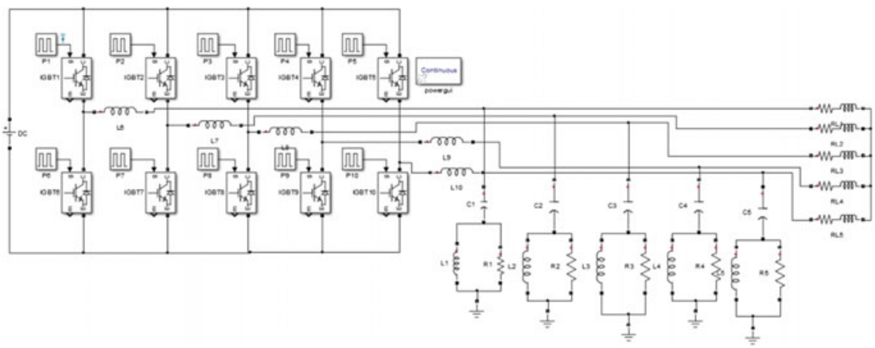

Fig. 2 Circuit diagram of five-phase inverter with high-pass filter

Table 1 Calculated values of parameters in high-pass filter for 15 Hz

R1–R5	90 Ω
C1–C5	1000 μF
L1–L5	129 mH

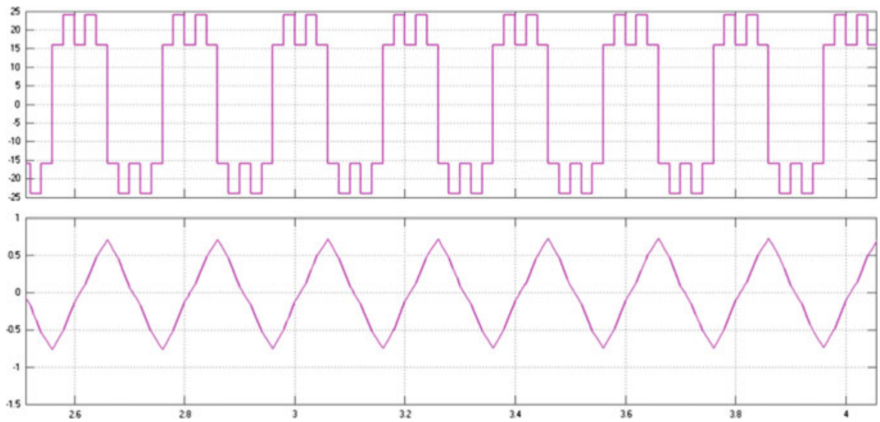

Fig. 3 Voltage and current of an individual phase in five-phase inverter

4 Simulation Results

Simulation has been done for the input frequency of 5 Hz and simulated with RL load for $R = 1.7\ \Omega$ and $L = 1.3$ mH which is employed to study the harmonic analysis of five-phase inverter drive. THD is also measured for both the inverters, voltage and current of an individual phase in five-phase inverter, without filter and using filter at the output of the inverter as shown in Figs. 3 and 4.

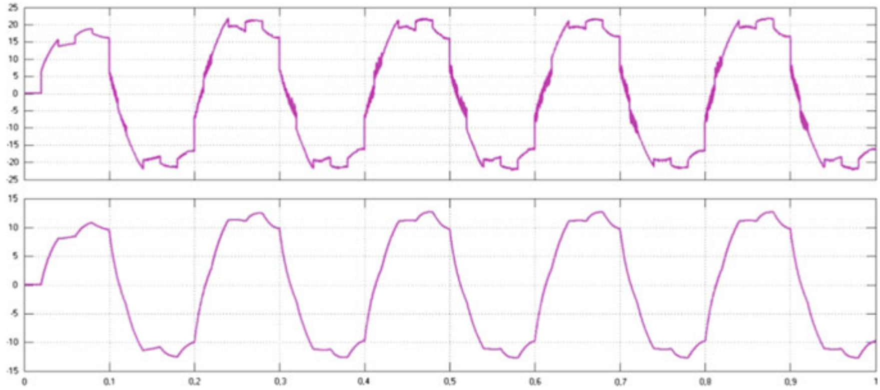

Fig. 4 Voltage and current of an individual phase in five-phase inverter with high-pass filter

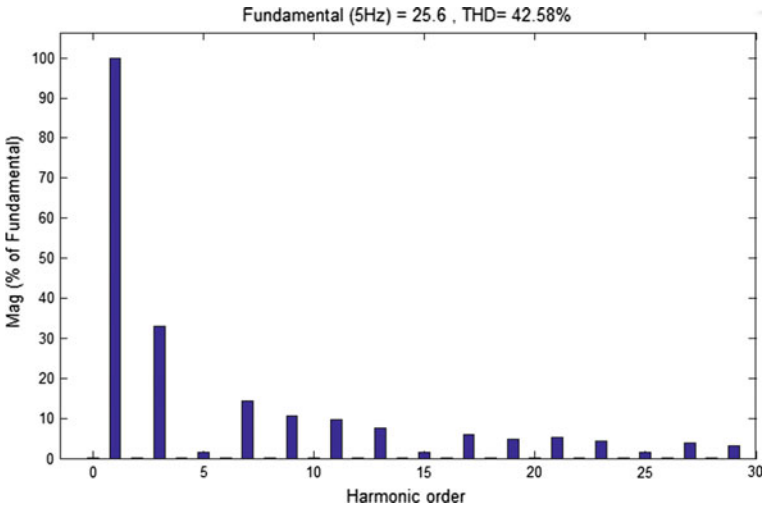

Fig. 5 Analysis of FFT in five-phase inverter

FFT analysis is used to measure the THD and harmonics at the load side of the five-phase inverter without filter and with high-pass filter as shown in Figs. 5 and 6, respectively. Table 2 shows overall total harmonic distortion of five-phase inverter without and with high-pass filter.

Table 3 shows the individual voltages of harmonic order of five-phase inverter without and with high-pass filter.

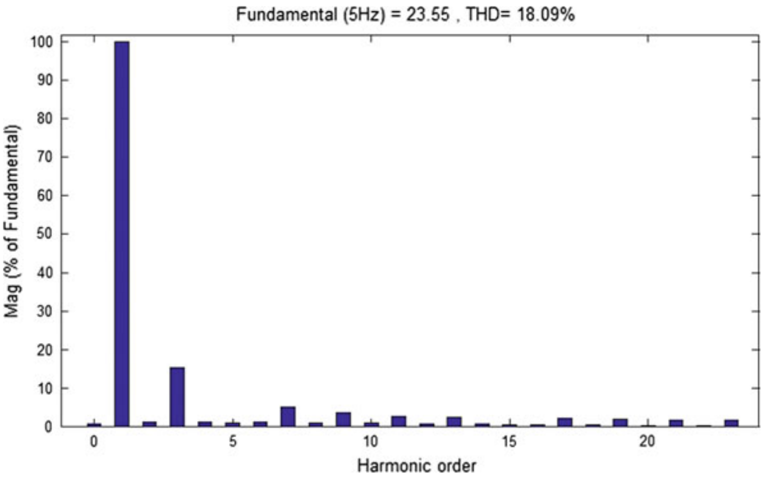

Fig. 6 Analysis of FFT of five-phase inverter with high-pass filter

Table 2 Overall THD of five-phase inverter without and with filter

Modes	THD in %
Five-phase inverter without filter	42.7
Five-phase inverter with series passive filter	20.07

Table 3 Individual voltage of harmonic order of five-phase inverter without and with high-pass filter

Harmonic order	Individual voltage of five-phase inverter without filter (normal) (V)	Individual voltage of five-phase inverter with high-pass filter (V)
1	25.46	23.51
3	8.48	3.55
5	0	0
7	3.63	1.42
9	2.82	1.03
11	2.31	0.81
13	1.95	0.66
15	0	0
17	1.49	0.49
19	1.34	0.43

5 Conclusion

The analysis of harmonics and total harmonic distortion of five-phase PWM inverter drive has been constructed and studied using MATLAB software. The circuit is simulated for the frequency $f = 15$ Hz for an input frequency of the inverter to eliminate the third harmonic order, which is the dominant harmonic in magnitude, that simply super imposed on the fundamental harmonic, it might be adverse effect on the performance of the five-phase inverter and also the harmonic reduction with THD has been analyzed and obtained the results. The comparison of harmonics and total harmonic distortion has been presented with normal five-phase PWM inverter and five-phase inverter using high-pass filter. It is found that the harmonics and THD are found to be less using high-pass filter. This work is used to study the stator heat analysis of five-phase asynchronous motor in future.

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Theoretical Analysis of the Electrical and Optical Properties of ZnS

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Abstract This chapter deals with the electrical and optical properties of ZnS by using the first principle plane-wave pseudopotential technique [ab initio *Technique*]. The obtained results show that the bandgap of ZnS system becomes narrow under the transition state condition, and also it changes the conductivity of ZnS from semiconductor to metal behavior. Zinc sulfide is a direct bandgap-type non-toxic semiconductor material. Moreover, it is used as an optical device. The above-mentioned properties show that the ZnS is a favorable candidate for luminous materials as well as solar photovoltaic cell. Doping of rare earth element and transition element in ZnS is used as a good phosphor material.

Keywords CASTEP · Bandgap · Dielectric · Reflectivity · IR spectrum Raman spectra

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1 Introduction

The non-toxic and wide bandgap semiconductor materials of the II–VI group such as zinc sulfide, zinc selenide, cadmium selenide, and cadmium sulfide are used as photo and electroluminescence materials. Zinc sulfide has a direct and wide bandgap semiconductor material (3.73 eV) along with the large band energy of exciton (37 meV). The above-mentioned properties signify that zinc sulfide is a favorable material for optical devices like ultraviolet LEDs [1–3], flat-panel displays [4, 5], solar photovoltaic cells [6], and sensor devices [7]. Zinc sulfide is an inorganic material which is in the form of sphalerite (cubic form) or zinc blende and wurtzite (hexagonal form). The material is an intrinsic semiconductor with a wide bandgap of about 3.54 eV for a cubic form of ZnS and 3.91 eV for hexagonal form. Such types of semiconductors are suitable for the analysis of discrete energy level states in the bandgap [2, 8, 9].

The optical, electrical, and electronic properties of semiconductors are likely to be characterized by the help of reflectivity, absorption spectra, and vibrational spectroscopy. The above optical constants depend upon photosensitive bandgap of the material.

In this work, the band structure, the density of states (DOS), dielectric functions, refractive index, absorption spectra, reflectivity, optical conductivity, and vibrational spectroscopy of ZnS are studied by the help of plane-wave pseudopotential method using density functional theory (DFT).

2 Computational Study by CASTEP

The computational study of zinc sulfide is performed by using the software code CASTEP [10] in the frame of density functional theory (DFT) with generalized gradient approximation (GGA) and the Perdew–Burke–Ernzerhof (PBE) as exchange functional [11–14]. The collaborations between ion and electron are represented by norm-conserving pseudopotentials for Zn and S atoms [15]. All the computing properties of ZnS used 380 eV as plane wave basis set cut-off energy, and k-point is $1 \times 1 \times 1$ Monkhorst–Pack [16] grid for the selection of the Brillouin zone. Geometrical optimization is conducted that 5×10^{-6} eV atom^{-1}: convergence thresholds for the total energy, 0.01 eV Å^{-1}: the maximum force, 0.02 Gpa: maximum stress and 5×10^{-4} Å: maximum displacement under the transition state method for DFT-D connections. BFGS method is used in a geometric optimization of ZnS [17, 18]. The space group number of sphalerite ZnS is F-43 M (216) [19, 20].

Generally in the study of the interface between light and matter, adiabatic and only electron approximation is used. The effect of phonon interaction in the transition process whether the intraband and interband is ignored since the transition frequency $\geq$ phonon frequency. According to the transition probabilities and