A R DIGITECH
International Journal Of Engineering, Education And Technology (ARDIJEET)
www.ardigitech.in,ISSN 2320-883X, VOLUME 1 ISSUE 1, 01/01/2013

Simulation of Digital PWM Generator for Inverter

Teju.R. Shukla *1, V. L. Jadhav*2, Soma. S. Mali *3
**1(Lecturers of E&TC Department,S.E.S. Polytechnic, Dhule, M.S. India)*
**2(Lecturers of E&TC Department,S.E.S. Polytechnic, Dhule, M.S. India)*
**3(Lecturers of E&TC Department,S.E.S. Polytechnic, Dhule, M.S. India)*
*shuklateju@gmail.com*1,vandanajadhav19jan@gmail.com*2,somamali71@gmail.com*3*

Abstract**:** *Pulse Width Modulation has nowadays become an integral part of every electronics system. These techniques have been widely accepted and are researched extensively nowadays. It has found its application in large number of applications as a voltage controller. Its use in controlling output voltage of Inverter is the most frequently used application. There are basically two main techniques of PWM Generation- Analog technique and Digital Technique. In the digital PWM technique sine PWM (SPWM) and space vector PWM (SVPWM) are included. SVPWM technique is more convenient and use in this project.*

Due to demerits of analog techniques digital techniques are studied. Various digital PWM Generator topologies are studied. The proposed system first implements the single phase inverter in MATLAB/SIMULINK environment. The output with different load is taken with the help of scope in matlab. The output contains the THD, with the FFT analysis THD percentage waveforms are get. The output of inverter being check with and without PWM controlled technique. Total harmonic distortion is reduced from output because of PWM technique. As the inductive load increases THD increases.

The power modules in the matlab are used for circuit simulation. It gives many advantages to first simulate the circuit and then implement it.

Keywords: Sine PWM (SPWM), Space Vector PWM (SVPWM), VHSIC Hardware Description Language (VHDL), Inverter.

I. Introduction

In the propose system, digital pulse width modulation (PWM) controlling technique is in development. The matlab used for designing the desire circuit of PWM generator.

The simulink offers the most preferred way of designing PWM generator for inverter. The power modules are used for designing. The IGBT switches are used because more convenient than MOSFET. Switching losses are very less. This design is economically suitable [1].

PWM modulation has nowadays become integral part of every electronics system. These techniques have been widely accepted and are researched extensively nowadays. It has found its application in large number of application. Its use in controlling output voltage of inverter is the most frequently used application for the generation of PWM, the digital technique is used because analog technique having some demerits.

Single phase pulse width modulated (PWM) inverters have found widespread application in uninterruptible power supplies (UPS) for telecommunication applications. The control strategy of a PWM inverter is one of the key aspects that influence its performance, size and cost. Many closed loop control strategies with the purpose of improving the output signal quality of a single-phase PWM inverter have been proposed.

Inverters are static power converters (DC to AC) that produce an AC output waveform from a DC power supply [3]. Inverters are applied in adjustable speed drives (ASDs), UPS etc. For the sinusoidal AC outputs, the magnitude, frequency and phase should be controllable [3]. Single phase inverters are those inverters which produces only single phase of AC output.

Single Phase Voltage Source Inverters

Single-phase VSI can be found as half bridge and full bridge topologies. Although the power range they cover is the low one, they are widely used in power supplies, single-phase UPS, and currently to form elaborate high power static power topologies, such as for instance, the multi cell configurations.

Half-Bridge VSI

Fig.1. shows the power topology of a half-bridge VSI, where two large capacitors are required to provide a neutral point N, such that each capacitor maintains a constant voltage (V_i)/2. Because the current harmonics injected by the operation of the inverter are low order harmonics, a set of large capacitors is required. It is clear that both switches S+ and S- cannot be ON simultaneously because a short circuit across the dc link voltage source V_i would be produced. There are two defined (states 1 and 2) and one undefined (state 3) switch state as shown in Table 3.1. In order to avoid the short circuit across the dc bus and the undefined ac output voltage condition, the modulating technique should always ensure that at any instant either the top or the bottom switch of the inverter leg is on.

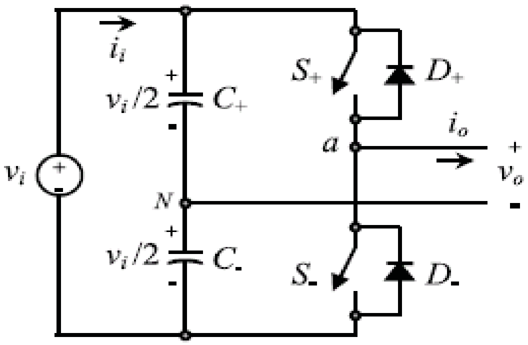

Fig1.: Single phase half bridge VSI.

Full-Bridge VSI

Fig. 3.2 shows the power topology of a full bridge VSI. This inverter is similar to the half bridge inverter; however, a second leg provides the neutral point to the load. As expected, both switches S1+ and S1- (or S2+ and S2-) cannot be on simultaneously because a short circuit across the dc link voltage source Vi would be produced.

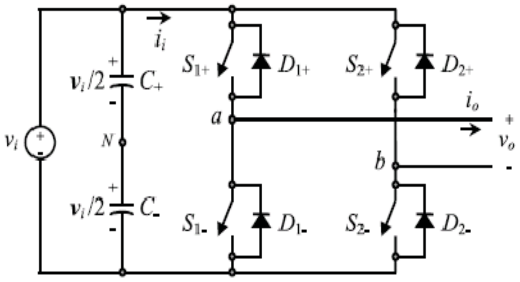

Fig.2.: Single phase full bridge VSI.

There are four defined (states 1, 2, 3, and 4) and one undefined (state 5) switch states as shown in Table 3.2. The undefined condition should be avoided so as to be always capable of defining the ac output voltage. It can be observed that the ac output voltage can take values up to the dc link value $V_{i,}$ which is twice that obtained with half bridge VSI topologies. Several modulating techniques have been developed that are applicable to full bridge VSI. Among them are the PWM (bipolar and unipolar) techniques.

Pulse Width Modulation Techniques in inverters

Output voltage from an inverter can also be adjusted by exercising a control within the inverter itself. The most efficient method of doing this is by pulse-width modulation control used within an inverter.

In this method, a fixed dc input voltage is given to the inverter and a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. This is the most popular method of controlling the output voltage and this method is termed as Pulse-Width Modulation (PWM) Control.

The advantages possessed by PWM techniques are as under:

(i) The output voltage control with this method can be obtained without any additional components.

(ii) With the method, lower order harmonics can be eliminated or minimized along with its output voltage control. As higher order harmonics can be filtered easily, the filtering requirements are minimized.

The main disadvantage of this method is that SCRs are expensive as they must possess low turn-on and turn-off times.

PWM inverters are quite popular in industrial applications. PWM techniques are characterized by constant amplitude pulses. The width of these pulses is however modulated to obtain inverter output voltage control and to reduce its harmonic content.

The different PWM techniques are as under:

(a) Single-pulse modulation.

(b) Multiple pulse modulation.

(c) Sinusoidal pulse width modulation (carrier based pulse width modulation technique).

Simulation And Model-Based Design

Simulink is a block diagram environment for multi domain simulation and model-based design. It supports system-level design, simulation, automatic code generation, and continuous test and verification of embedded systems. Simulink provides a graphical editor, customizable block libraries, and solvers for modeling and simulating dynamic systems. It is integrated with matlab, enabling you to incorporate matlab algorithms into models and export simulation results to matlab for further analysis.

Simulation of SPWM

In SPWM three phase reference modulating signals are compared against a common triangular carrier to generate the PWM signals for the three phases. It is simple and linear between 0% and 78.5% of six step voltage values, which results in poor voltage utilization. Frequency in conventional SPWM output waves owing to their fixed switching frequencies. Simulation has been carried out by varying the modulation index between 0 and 1.Finally performance of chaos based SPWM has been compared with SPWM [3].

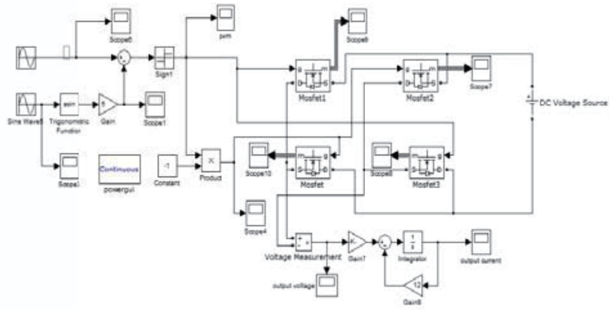

Fig.3: Simulation of SPWM

Fig.3 shows the simulated diagram of SPWM generator. The sine wave is the input of the generator. It is the original signal act as modulating signal.The carrier signal is add with this modulating signal.The width of the signal is vary in the output voltage.Various blocks from power liabrary taken for this circuit.

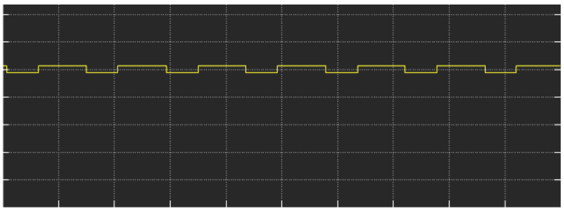

Fig.4: Output Voltage of SPWM controlled inverter

Fig.4. shows the output voltage of SPWM controlled inverter. The width of the voltage signal varies continuously. The voltage is stable than PWM signal.

Simulation of SVPWM

SVPWM is an advanced technique used for variable frequency drive applications. It utilizes dc bus voltage more effectively and generates less THD in the three phase voltage source inverter. SVPWM utilize a chaotic changing switching frequency to spread the harmonics continuously to a wide band area so that the peak harmonics can be reduced greatly. Simulation has been carried out by varying the modulation index between 0 and 1. Finally performance of SVPWM has been compared with conventional SPWM.

Generalized MATLAB/SIMULINK Model of SVPWM

This section details the step by step development of a matlab/simulink based simulation model for implementing both continuous and discontinuous SVPWM. By slight modification in the matlab function code different types of SVPWM can be realized. Thus the presented simulation mode is general in nature and can be configured very easily to simulate continuous and discontinuous SVPWM in linear modulation range.

Reference Voltage Generation Block

This block is used to simulate balanced phase input reference. Three-phase input sinusoidal voltage is generated using ‘function’ block from ‘Functions & Tables’ sub library of simulink. This is then converted into two-phase equivalent using Clark’s transformation equations. This is once again implemented using the ‘function’ blocks. Further the two-phase equivalent is transformed to polar form using ‘Cartesian to polar’ block from ‘Simulink extras’ sub-library. The output of this block is the magnitude of the reference as the first output and the corresponding angle of the reference as the second output. The waveform of magnitude is simply a constant line as its value remains fixed. It is a saw tooth signal with peak value of $\pm\pi$. Sector identification is done using the comparison of the angle waveform with the predefined values. The number inside the waveform represents the sector number

Switching Time Calculation

The switching time and corresponding switch state for each power switch is calculated in Matlab function block. The matlab code requires magnitude of the reference, the angle of the reference and timer signal for comparison. The angle of the reference voltage is kept constant for one sampling period using ‘zero order hold’ block so that its value does not change during time calculation. Further, a ramp time signal is required to be generated to be used in matlab code. The height and width of the ramp signal is equal to the switching time of inverter branch. This ramp is generated using ‘repeating sequence’ from the source sub library. The matlab code should firstly identify the sector of the reference voltage. The time of application of active and zero vectors are then need to be calculated. The times are required to be arranged according to the predefined switching pattern. This time needs to be compared with the ramp timer signal. The height and width of the ramp is equal to the switching period of the inverter branch. Depending upon the location of the time signal within the switching period, the switch state is defined. This switch state is then passed on to the inverter block for further calculation [2].

Inverter Block

This block is built to simulate a voltage source inverter assuming constant dc link voltage. The inputs to the inverter block are the switching signals and the outputs are the PWM phase-to-neutral voltages. The inverter model is built using ‘function’ blocks.

Inverter as System Part In MATLAB/ SIMULNK

The single phase full controlled inverter is designed in the MATLAB/SIMULINK software, using power modules.

The result of the circuit is the digital voltage shown in fig.4.3. The fig.4.4 shows the circuit implementation.

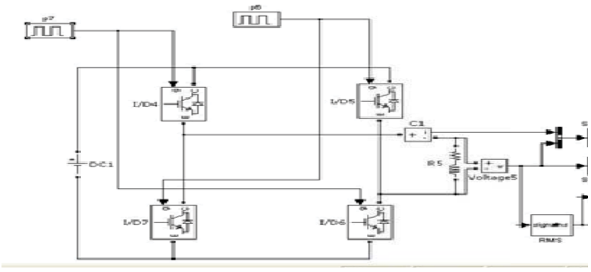

Fig.5: Single Phase Full Controlled inverter using MATLAB/SIMUL

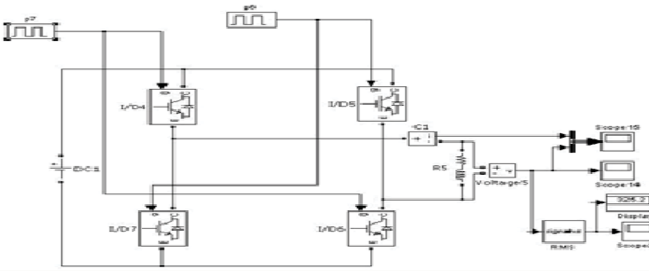

Fig.6: Single Phase Full Controlled inverter with digital output

Following graphs shows the observation of inverter circuit with different loads. In the graph 4.2 and 4.3 the output voltage and current respectively observed for R=10□, L=3H.

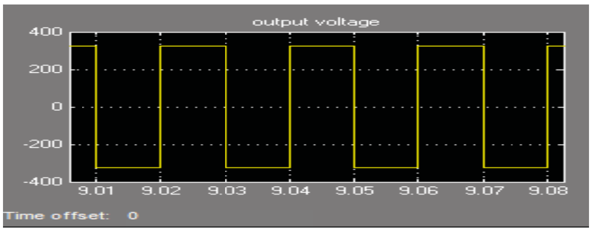

Fig. 7: Output voltage of single phase full controlled inverter (R=10□, L=3H)

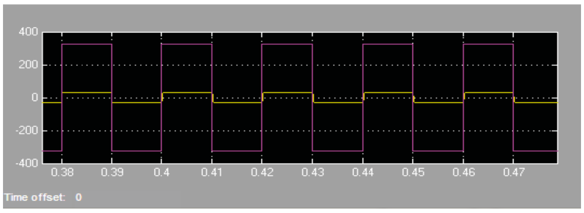

Fig.8: Output current waveform of single phase full controlled inverter (R=10□, L=3H**)**

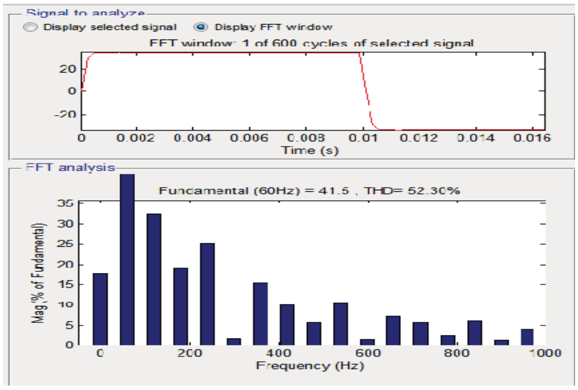

Fig 9: FFT analysis of single phase full controlled inverter (R=10□, L=3H)

In the following Fig.10 and 11 observations for voltage and current when load is set as R=50□, L=20H.

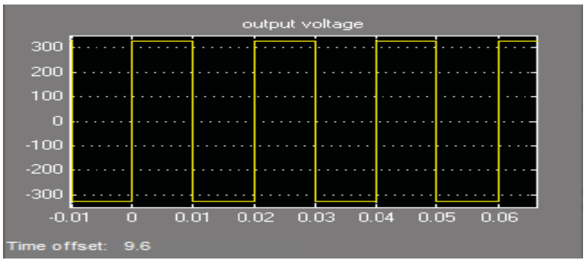

Fig.10: Output voltage of single phase full controlled inverter (R=50□, L=20H)

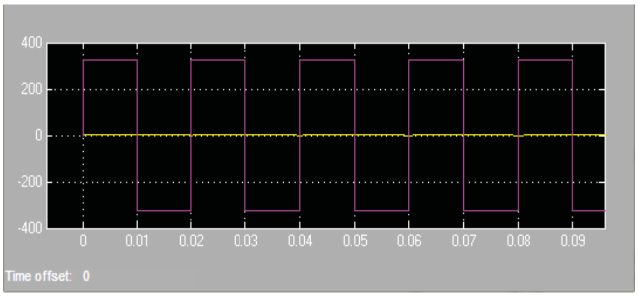

Fig 11: Output current waveform of single phase full controlled inverter (R=50□, L=20H)

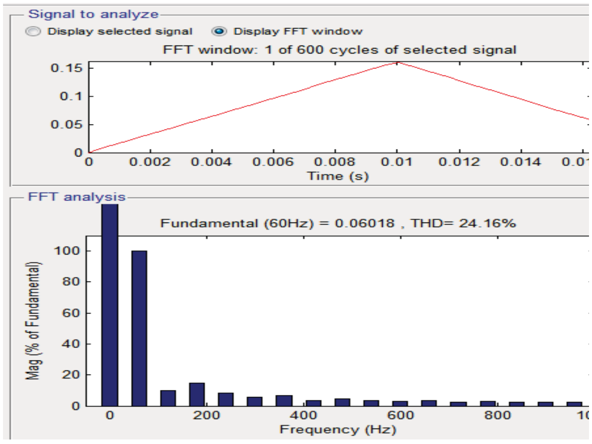

Fig.12: FFT analysis of single phase full controlled inverter (R=50Ω, L=20H)

The fig. 11 and 12 shows the output waveforms for the load R= 5Ω, L=30H. The all observation shows that the constant output voltage and current for each load. Either load is heavy or light the output is constant by using digital PWM method

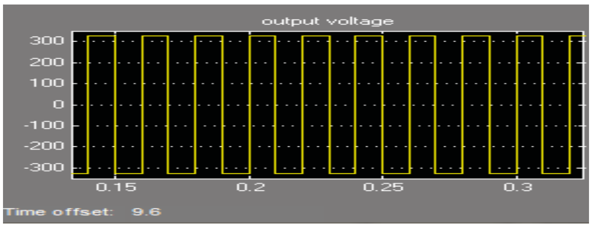

Fig 13: Output voltage of single phase full controlled inverter (R= 5Ω, L=30H)

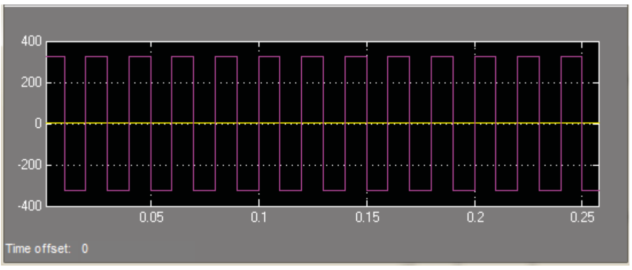

Fig 14: Output current of single phase full controlled inverter (R= 5Ω, L=30H)

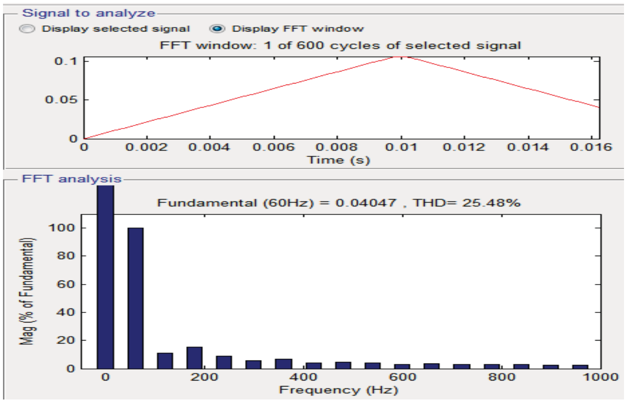

Fig 15: FFT analysis of single phase full controlled inverter (R= 5Ω, L=30H)

The FFT analysis of the output at each load is as shown in the graph 4.4, 4.7, 4.10 etc. The FFT signal shows the THD= 52.30%for load R= 10Ω and L= 3H. The THD =24.16%for the load R=50Ω, L=20H. For the load R= 5Ω, L=30H the THD=25.48%.Athe inductive load decreases the THD decreases. To improve the output and reduce the THD SVPWM is applied to the circuit.

The IGBT module is suitable for many applications in power electronics, especially in PWM servo and three-phase drives requiring high dynamic range control and low noise. It also can be used in UPS, SMPS, and other power circuits requiring high switch repetition rates. IGBT improves dynamic performance and efficiency and reduced the level of audible noise. It is equally suitable in resonant-mode converter circuits. Optimized IGBT is available for both low conduction loss and low switching loss.

REFERENCES

[1] Cassiano Rech, Humberto Pinheiro, Hilton Abílio Grundling,Hélio Leaes Hey,and José Renes Pinheiro, "Comparison of Digital Control Techniques With Repetitive Integral Action for Low Cost PWM Inverters" IEEE Transactions On Power Electronics, Vol. 18, No. 1, pp. 401-410, January 2003.

[2] Yasser Abdel-Rady Ibrahim Mohamed And Ehab F. El-Saadany, "An Improved Deadbeat Current Control Scheme With A Novel Adaptive Self-Tuning Load Model For A Three-Phase PWM Voltage-Source Inverter" IEEE Transactions on Industrial Electronics, Vol. 54, No. 2, pp. 747-759, April 2007.

[3] Sidney R. Bowes, and Derrick Holliday, "Optimal Regular-Sampled PWM Inverter Control Techniques" IEEE Transactions on Industrial Electronics, Vol. 54, No. 3,pp. 1547-1559, June 2007.

[4] Rajesh Gupta, Arindam Ghosh and Avinash Joshi, "Switching Characterization of Cascaded Multilevel-Inverter-Controlled Systems" IEEE Transactions on Industrial Electronics, Vol. 55, No. 3, pp. 1047-1058, March 2008.

[5] Rajesh Gupta, Arindam Ghosh, and Avinash Joshi, "Characteristic Analysis for Multisampled Digital Implementation of Fixed-Switching-Frequency Closed-Loop Modulation of Voltage-Source Inverter", IEEE Transactions on Industrial Electronics, Vol. 56, No. 7, pp.2382-2393, July 2009.

[6] Huifeng Mao, Xu Yang, Zenglu Chen, and Zhaoan Wang, "A Hysteresis Current Controller for Single-Phase Three-Level Voltage Source Inverters" IEEE Transactions on Power Electronics, Vol. 27, No. 7, pp.3330-3339, July 2012.

[7] Anshul Agarwal and Vineeta Agarwal, "FPGA Realization of Trapezoidal PWM for Generalized Frequency Converter", IEEE Transactions on Industrial Informatics, Vol. 8, No. 3, pp.501-510, August 2012.

[8] Radu Iustin Bojoi, Leonardo Rodrigues Limongi, Daniel Roiu, and Alberto Tenconi, "Enhanced Power Quality Control Strategy for Single-Phase Inverters in Distributed Generation Systems" IEEE Transactions on Power Electronics, Vol. 26, No. 3, pp. 798-806, March 2011.

[9] Tejas M. Bhatt, Dennis McCain, "Matlab as a Development Environment for FPGA Design", DAC Anaheim, California, USA, pp.13-17, June 2005.

[10] Jens Onno Krah, Markus Höltgen, Andreas Rath Rolf Richter, "FPGA-based Control of Three-Level Inverters" PCIM Europe, pp. 17-19, May 2011.

[11] Prawin Angel Michael, K.Vinoth Kumar, S.Suresh Kumar, N.Devarajan, "Implementation of SVPWM in FPGA through MATLAB/SIMULNK Environment", International Journal of Engineering Science and Technology Vol. 2(9), pp.4585-4594, 2010.

[12] K. Vinoth Kumar, Prawin Angel Michael, Joseph P. John and Dr. S. Suresh Kumar, "Simulation and comparison of SPWM and SVPWM control for three phase inverter", ARPN Journal of Engineering and Applied Sciences, Vol. 5, pp. 7 July 2010.

[13]Nazeih Botros, "HDL programming fundamentals: VHDL and Verilog" Da Vinci Engineering press, Bostan, 2007. (Book)

[14]Charles H. Roth, "Digital systems design using VHDL". Thomson Asia. Singapore, 2002. (Book)

[15]Ned Mohan, T.M. Undeland and W.P. Robbins, "Power electronics, converters application, and design", John Wiley and sons, third edition, 2010. (Book)

[16]M.H. Rashid, "Power electronics circuits, devices and application" third edition, Pearson education, 2012. (Book)