Sinusoidalisation of the Input Current In Boost Type Rectifier using Sigma-Delta Modulation Schemes

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Abstract- Almost all the rectifier circuits introduce the harmonics to the input side. In this project it is attempted to reduce the effect of the harmonics due to the rectifier or the switch mode power supplies (SMPS) on the supply side. In order to attain the sinusoidalisation of the supply side current. Different PWM techniques like resistance emulation have been introduced before. This project uses the Sigma Delta Modulation (SDM) technique to remove the harmonic content that is introduced to the supply side current. This technique would involve in the wave shaping of the input side current just by using the PWM technique. The sinusoidalisation is the method in which the Harmonic Distortion in the supply side also gets reduced without adding extra hardware. In conventional method input current and voltage are much distorted as compare to sigma delta modulation. The Matlab based simulation of the boost converter with the SDM PWM method is attempted and the results are taken.

Keywords- Boost Converter, Pulse Width Modulation, Switch Mode Power Supplies (SMPS), Sigma Delta Modulation (SDM)

I.INTRODUCTION

To meet the requirements of international standards such as IEC61000-3-2 and IEEE519, Boost-type rectifiers (BTR) have been employed in a large variety of industrial applications of switch-mode power supplies. Input power factor correction and output voltage regulation in the BTR are mandatory requirements. To this end the input current in a BTR must be in phase with the input voltage and there should be little harmonic distortion. The major cause of low-frequency harmonics in the input current is current distortion near voltage zero crossings. By means of various current control methods and proper input inductor selection, reduction of the input current harmonics has been attempted. The majority of these approaches use the conventional PWM with a fixed switching period, which is usually implemented using PWM integrated circuits. As gate circuits for boost switchers have recently been embedded in switching devices, a simple digital method to generate switching pulse waveform in a DSP or microprocessor is more efficient than the conventional PWM scheme.

In this work, sigma–delta modulation (SDM) schemes are presented with the objective of harmonic reduction of the input current in a BTR. There are three advantages over the conventional PWM. The first is that the dominant low frequency harmonics in the input current are reduced because the SDM makes the switching instances of the boost switcher vary randomly and configure relatively longer switch on-time at the start of each half cycle than for the conventional PWM. These effects allow the input current in a BTR to be sinusoidal and to have less low harmonic distortion. Secondly, the SDM is similar to randomized PWM in that it attempts to disperse the spectrum over a continuous range of frequencies. The harmonic spikes around the switching frequency in the conventional PWM are suppressed and mitigation of the conducted EMI can be achieved. Lastly the SDM schemes can be easily implemented using several software sentences on a DSP or microprocessor because the switching pulse waveform can be configured without calculating the on/off-time duration. The input-current waveforms and their frequency spectra are observed for each modulation scheme. The harmonic distortion is compared to evaluate the harmonic reduction of the input current in the BTR.

II. EXPERIMENTATION & METHODOLOGY

2.1 Introduction to Matlab

2.1.1 Sim Power Systems

Sim Power Systems and Sim Mechanics of the Physical Modeling product family work together with Simulink to model electrical, mechanical and control systems.

2.1.2 Role of Simulation in Design

Electrical power systems are combinations of electrical and electromechanical devices like motors and generators. Engineers working in this discipline are constantly improving the performance of the systems. Requirements for drastically improved efficiency have forced power system designers to use power electronic devices and sophisticate control system concepts that tax traditional analysis tools and techniques. Further complicating the analyst's role is the fact that the system is often so nonlinear that the only way to understand it is through simulation.

Land based power generation from hydroelectric, steam or other devices are not the only use of power systems. A common attribute of these systems is their use of power electronics and control systems to achieve their performance objectives.

Sim Power Systems is a modern tool that allows scientists and engineers to rapidly and easily build models that simulate power systems. Sim Power Systems uses the Simulink environment, allowing building a model using simple click and drag procedures. Not only can draw the circuit topology rapidly, but analysis of the circuit can include its interactions with mechanical, thermal, control, and other disciplines. This is possible because all the electrical parts of the simulation interact with the extensive Simulink modeling library. Since Simulink uses MATLAB as its computational engine, designers can also use MATLAB toolboxes and Simulink block sets. Sim Power Systems and Sim Mechanics share a special Physical Modeling block and connection line interface.

2.1.3 Sim Power Systems Libraries

Sim Power Systems can be made to work rapidly. The libraries contain models of typical power equipment such as transformers, lines, machines and power electronics. These models are proven ones coming from textbooks and their validity is based on the experience of the Power Systems testing and Simulation Laboratory of Hydro Quebec, a large North American utility located in Canada and also on the experience of Ecole de Technologies superior.

The capabilities of Sim Power Systems for modeling typical electrical systems are illustrated in demonstration files. And for users who want to refresh their knowledge of power system theory, there are also self-learning case studies.

2.2 Design and Simulating of a Simple Circuit

Sim Power Systems allows building and simulating of electrical circuits containing linear and nonlinear elements.
In this section it is possible to

1. Explore the powerlib library of Sim Power Systems
2. Learn how to build a simple circuit from the powerlib library
3. Interconnect Simulink blocks with your circuit

This section contains discussion of the following topics:

1. Building the Electrical Circuit with powerlib Library
2. Interfacing the Electrical Circuit with Simulink
3. Measuring Voltages and Currents
4. Basic Principles of Connecting Capacitors and Inductors
5. Using the Powerlib Block to Simulate SimPowerSystems Models

2.3 Designing a Electrical Circuit with Powerlib Library

The graphical user interface makes use of the Simulink functionality to interconnect various electrical components. The electrical components are grouped in a special library called powerlib.

SimPowerSystems library is opened by entering the following command at the MATLAB prompt. Powerlib this command displays a Simulink window showing icons of different block libraries.

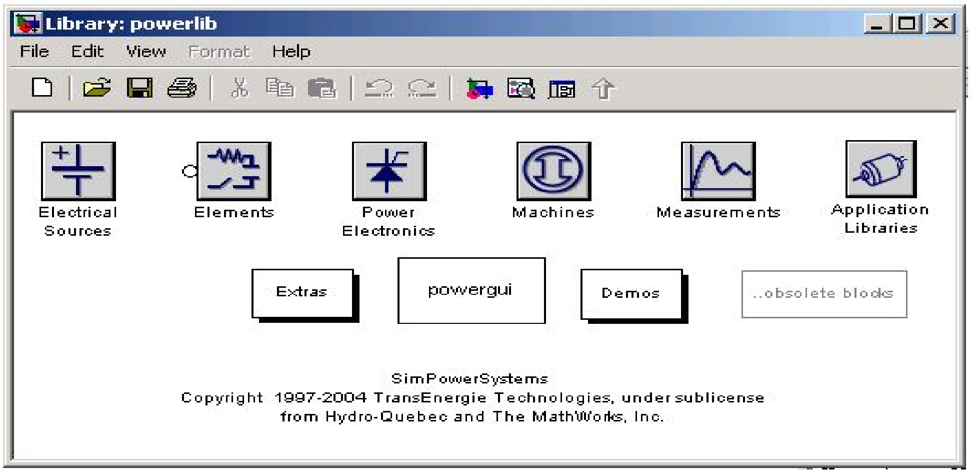

Fig 2.3 Powerlib Library

It is possible to open these libraries to produce the windows containing the blocks to be copied into given circuit. Each component is represented by a special icon having one or several inputs and outputs corresponding to the different terminals of the component.

2.4 Interfacing Electrical Circuit with Simulink

The Voltage Measurement block acts as an interface between the SimPowerSystems blocks and the Simulink blocks. The Voltage Measurement block converts the measured voltages into Simulink signals. The Current Measurement block from the Measurements library of powerlib can also be used to convert any measured current into a Simulink signal.

It is also possible to interface from Simulink blocks to the electrical system. For example, it is possible to use the Controlled Voltage Source block to inject a voltage in an electrical circuit, as shown in the following figure 2.4.

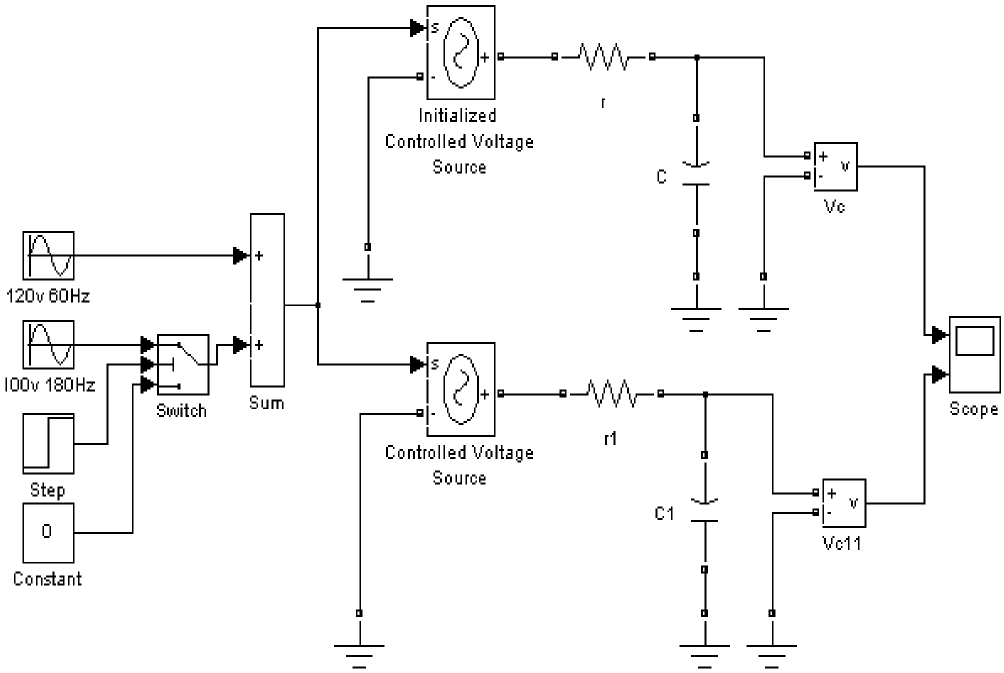

Fig 2.4 Interfacing electrical circuit with simulink

2.5 Measuring Voltages and Currents

To measure a current using a Current Measurement block, the positive direction of current is indicated on the block icon (positive current flowing from positive terminal to negative terminal). Similarly, when to measure a voltage using a Voltage Measurement block, the measured voltage is the voltage of the positive terminal with respect to the negative terminal. However, when voltages and currents of blocks from the Elements library are measured using the Multi-meter block, the voltage and current polarities are not immediately obvious because blocks might have been rotated and there are no signs indicating polarities on the block icons. Unlike Simulink signal lines and input and output ports, the Physical Modeling connection lines and terminal ports of SimPowerSystems lack intrinsic directionality. The voltage and current polarities are determined, not by line direction, but instead by block orientation.

III. CONTROL PRINCIPLES

A dc-dc converter must provide a regulated dc output voltage under varying load and input voltage conditions. The converter component values are also changing with time, temperature, and so forth. Hence, the control of the output voltage should be performed in a closed-loop manner using principles of negative feedback. The two most common closed-loop control methods for PWM dc-dc converters, namely, the voltage-mode control and the current-mode control, are presented schematically.

In the voltage-mode control scheme shown. The converter output voltage is sensed and subtracted from an external reference voltage in an error amplifier. The error amplifier produces a control voltage that is compared to a constant-amplitude sawtooth waveform. The comparator produces a PWM signal that is fed to drivers of controllable switches in the dc-dc converter. The duty ratio of the PWM signal depends on the value of the control voltage. The frequency of the PWM signal is the same as the frequency of the sawtooth waveform. An important advantage of the voltage-mode control is its simple hardware implementation and flexibility.

The error amplifier in Fig. 5.6 reacts fast to changes in the converter output voltage. Thus, the voltage-mode control provides good load regulation, that is, regulation against variations in the load. Line regulation (regulation against variations in the input voltage) is, however, delayed because changes in the input voltage must first manifest themselves in the converter output before they can be corrected. To alleviate this problem, the voltage-mode control scheme is sometimes augmented by a so-called voltage-feed forward path. The feed forward path affects directly the PWM duty ratio according to variations in the input voltage. As will be explained in what follows, the input voltage feed forward is an inherent feature of current-mode control schemes.

The current-mode control scheme is presented in figure 4.1. An additional inner control loop feeds back an inductor current signal, and this current signal, converted into its voltage analog, is compared to the control voltage. This modification of replacing the sawtooth waveform of the voltage-mode control scheme by a converter current signal significantly alters the dynamic behavior of the converter, which then takes on some characteristics of a current source.

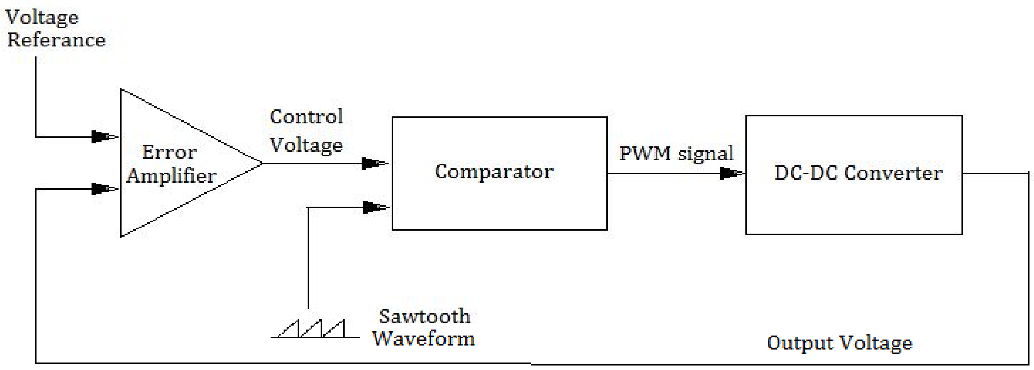

Fig (a)

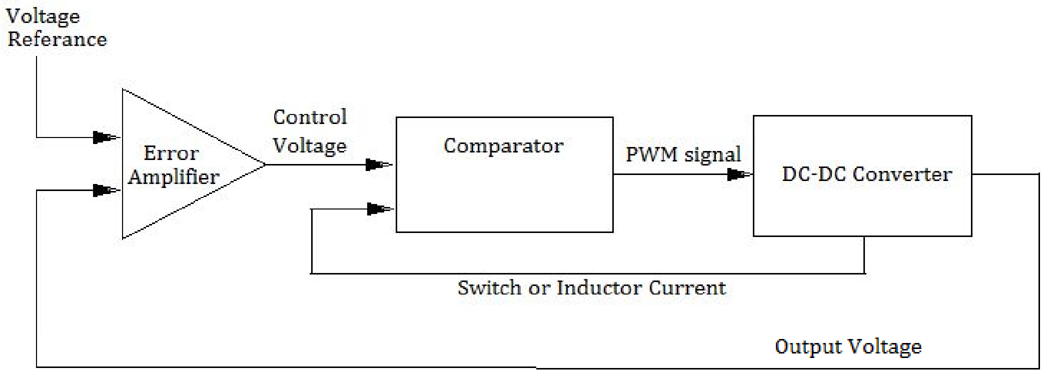

Fig (b)

Fig 3.1. Controller Block diagram

The output current in PWM dc-dc converters is either equal to the average value of the output inductor current (buck-derived and Cuk converters) or is a product of an average inductor current and a function of the duty ratio. In practical implementations of the current-mode control, it is feasible to sense the peak inductor current instead of the average value. As the peak inductor current is equal to the peak switch current, the latter can be used in the inner loop, which often simplifies the current sensor. Note that the peak inductor (switch) current is proportional to the input voltage. Hence, the inner loop of the current-mode control naturally accomplishes the input voltage-feed forward technique. Among several current-mode control versions, the most popular is the constant-frequency one that requires a clock signal. Advantages of the current- mode control are the input voltage feed forward, the limit on the peak switch current, the equal current sharing in modular converters, and the reduction in the converter dynamic order. The main disadvantage of the current-mode control is its complicated hardware, which includes a need to compensate the control voltage by ramp signals (to avoid converter instability). Among other control methods of dc-dc converters, a hysteretic (or bang-bang) control is very simple for hardware implementation. However, the hysteretic control results in variable frequency operation of semiconductor switches. Generally, a constant switching frequency is preferred in power electronic circuits for easier elimination of electromagnetic interference and better utilization of magnetic components.

IV. EXPERIMENTAL SETUP

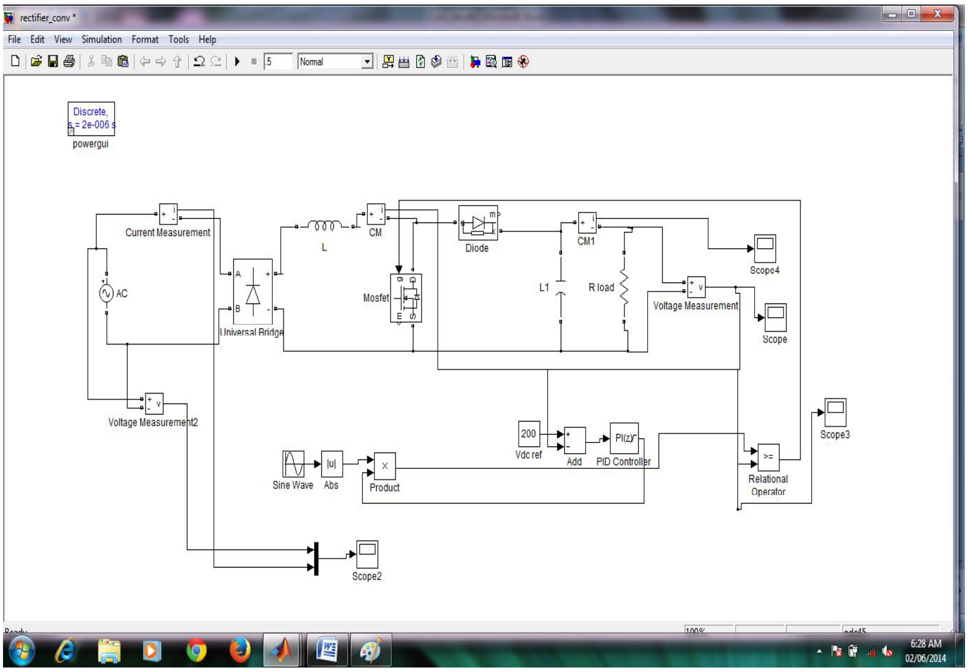

Fig 4.1 Circuit Diagram of conventional rectifier using MATLAB SIMULINK

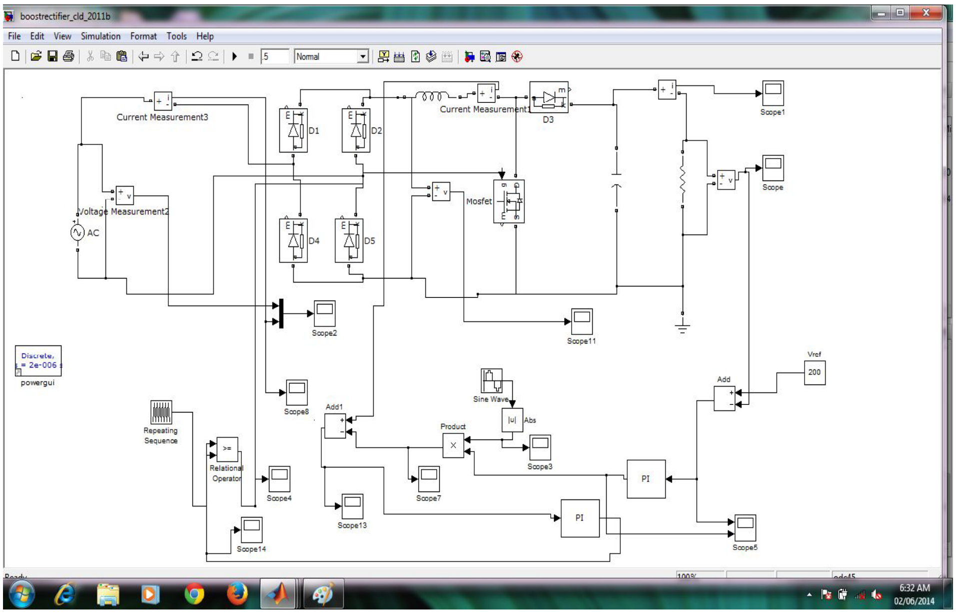

Fig 4.2 Circuit Diagram of Bosst type rectifier using MATLAB SIMULINK

V. RESULTS

WAVEFORMS OF CONVENTIONAL METHOD

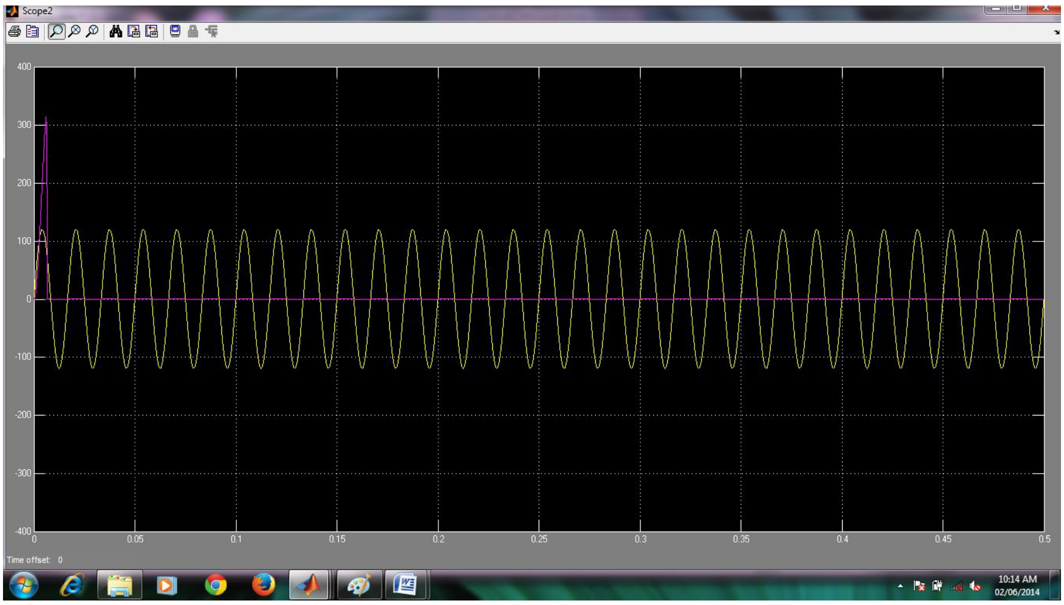

Fig 5.1 a) Voltage and current wave forms at 25 ohms load.

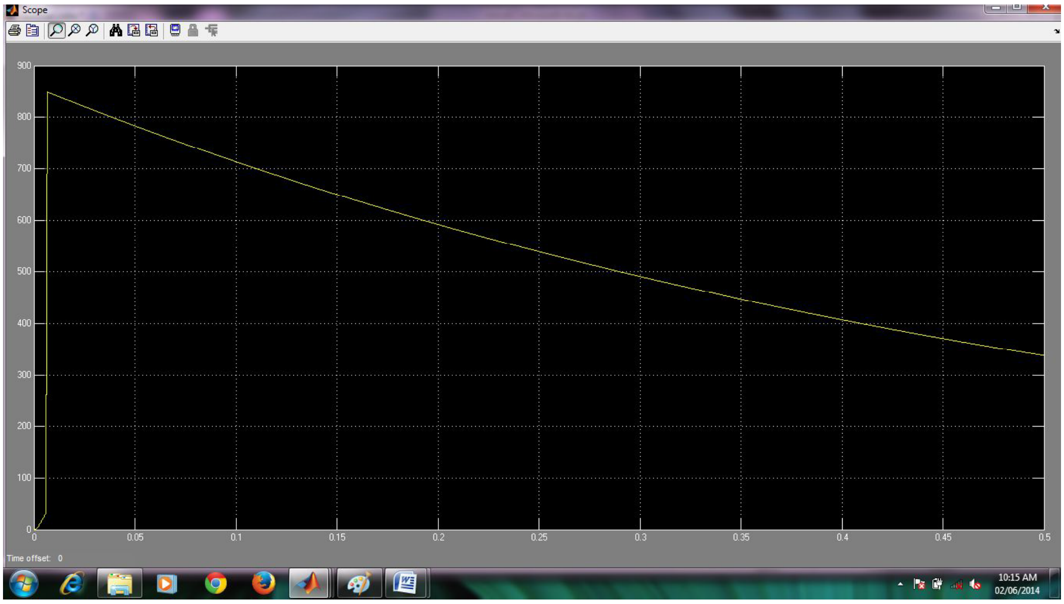

Fig 5.1 b) Output Voltage wave forms at 25 ohms load.

Fig 5.1 c) Output current wave forms at 25 ohms load.

Fig 5.2 a) Voltage and current wave forms at 250 ohms load.

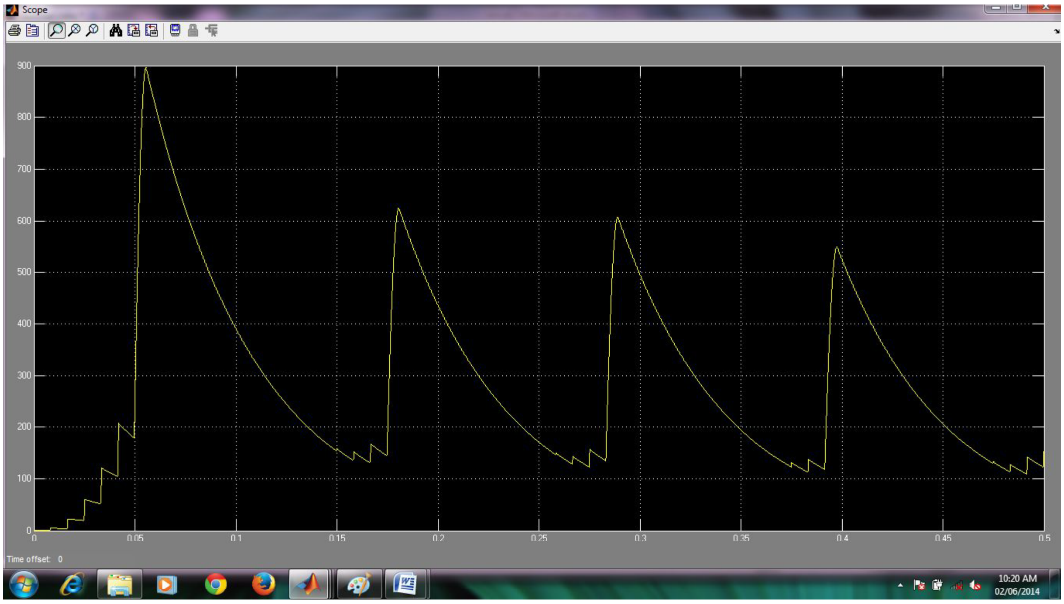

Fig 5.2. b) Output Voltage wave form at 250 ohms load.

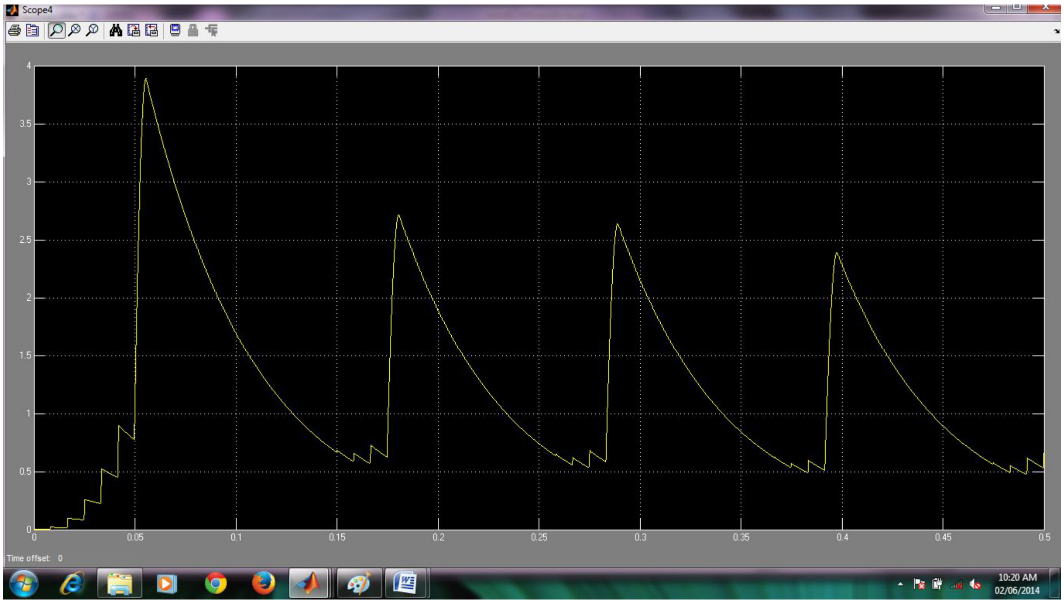

Fig 5.2 c) Output current wave forms at 250 ohms load.

In conventional rectifier (i.e. PWM) ripples are more at the output side because of non linear load (Inductance).Due to this the input voltage and current are also get distorted. These variations can be seen in the above waveforms. To avoid the distortion a new method is incorporated that is Sigma Delta Modulation.. This will be analyzed in coming discussion.

WAVEFORMS OF SIGMA DELTA METHOD

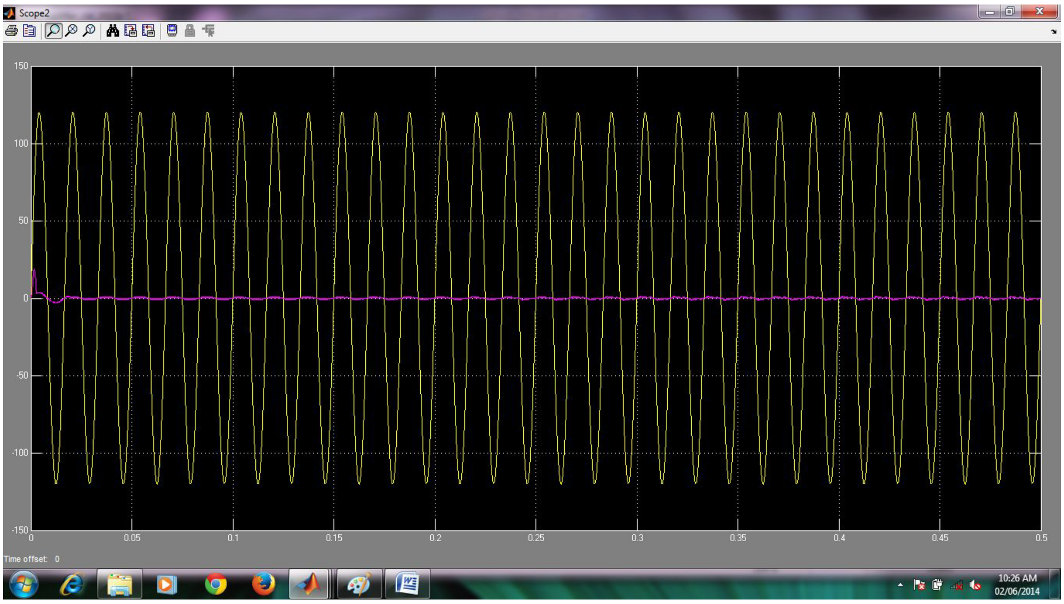

Fig 5.3 a) Voltage and current wave forms at 25 ohms load.

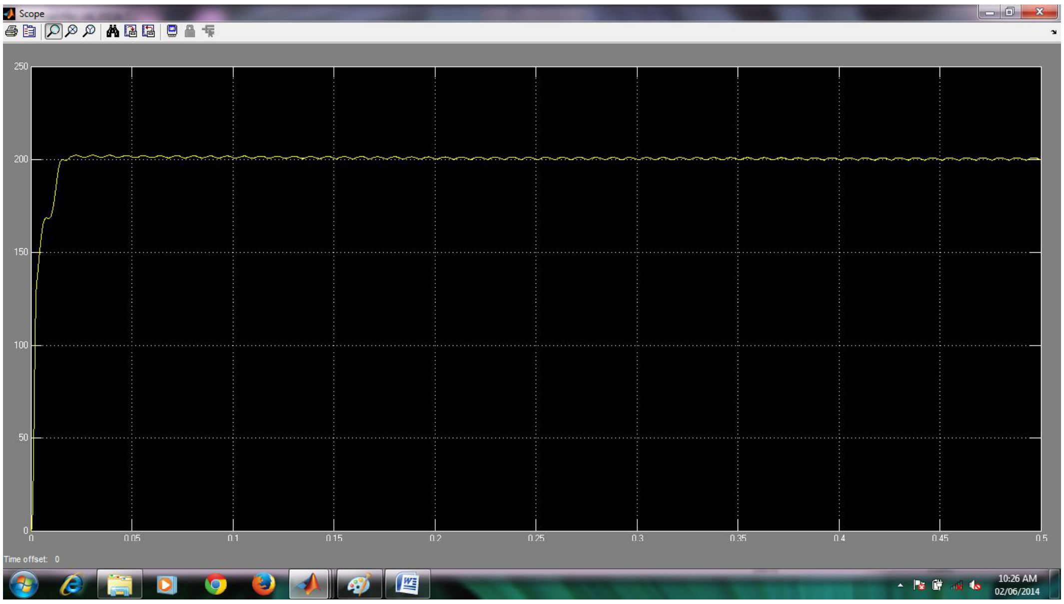

Fig 5.3 b) Output Voltage wave forms at 25 ohms load.

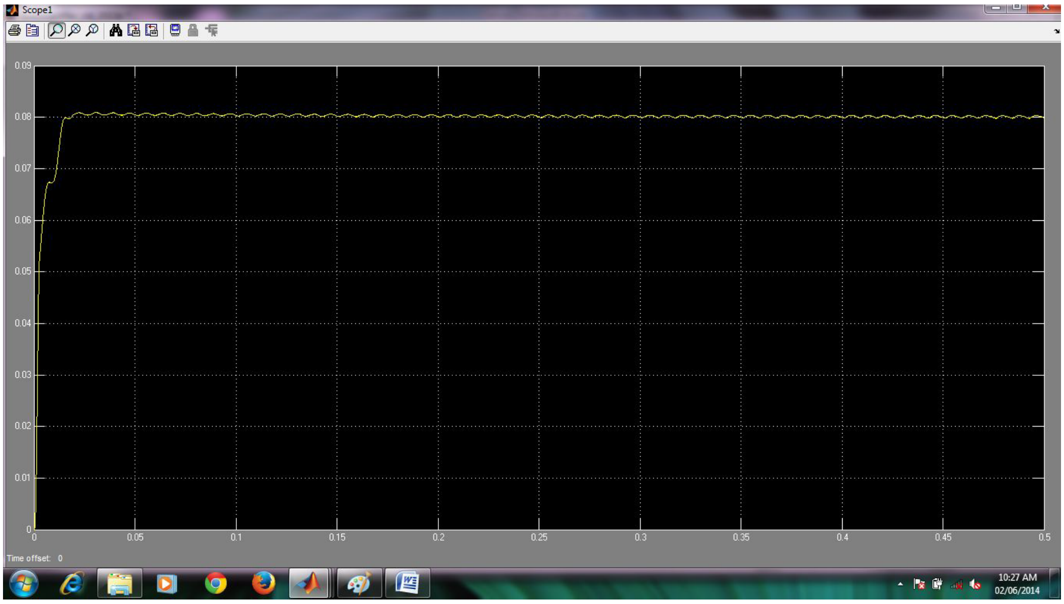

Fig 5.3 c) Output Current wave forms at 25 ohms load.

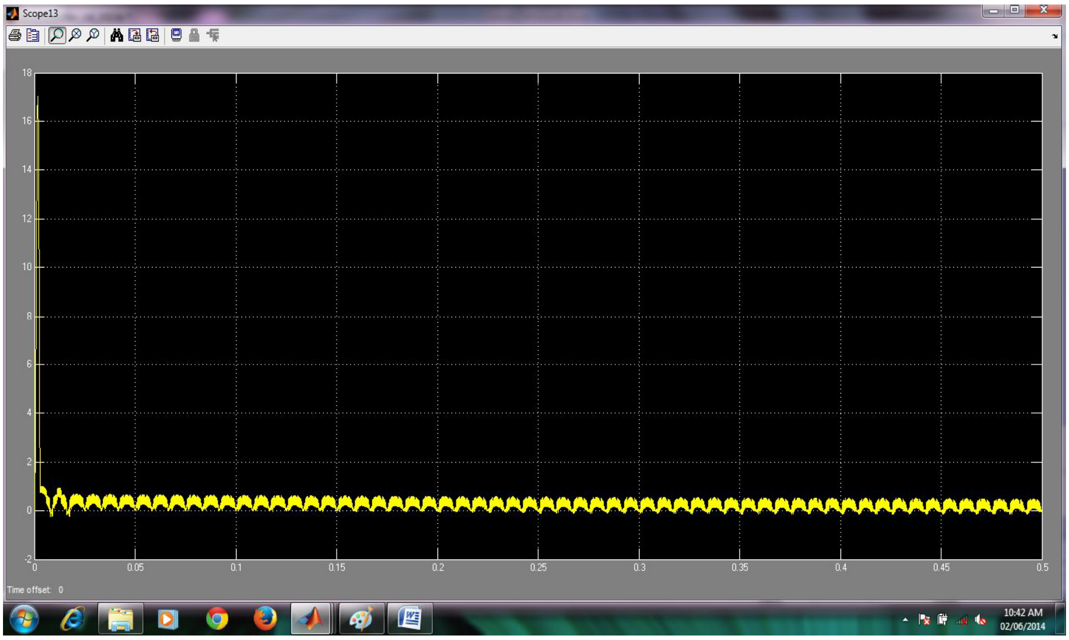

Fig 5.3 d) Current Error at 25 ohms load.

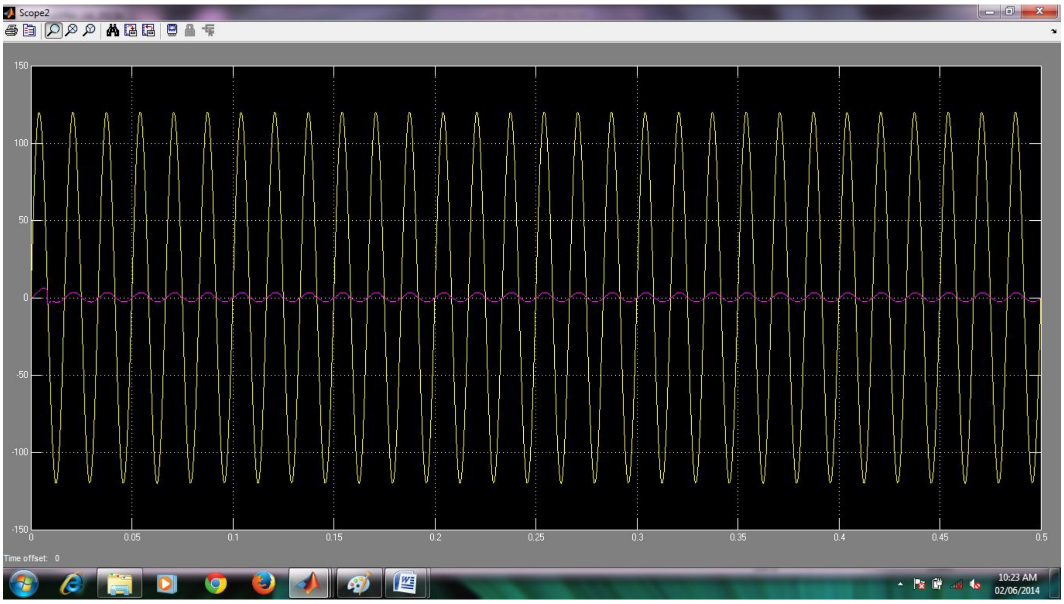

Fig 5.4 a) Voltage and current wave forms at 250 ohms load.

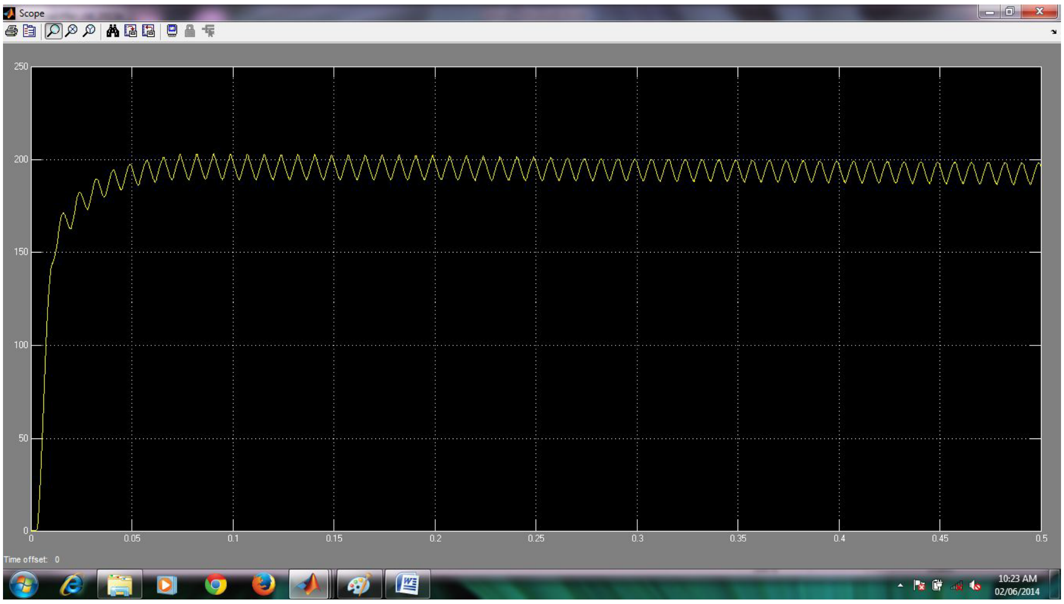

Fig 5.4 b) Output Voltage wave form at 250 ohms load.

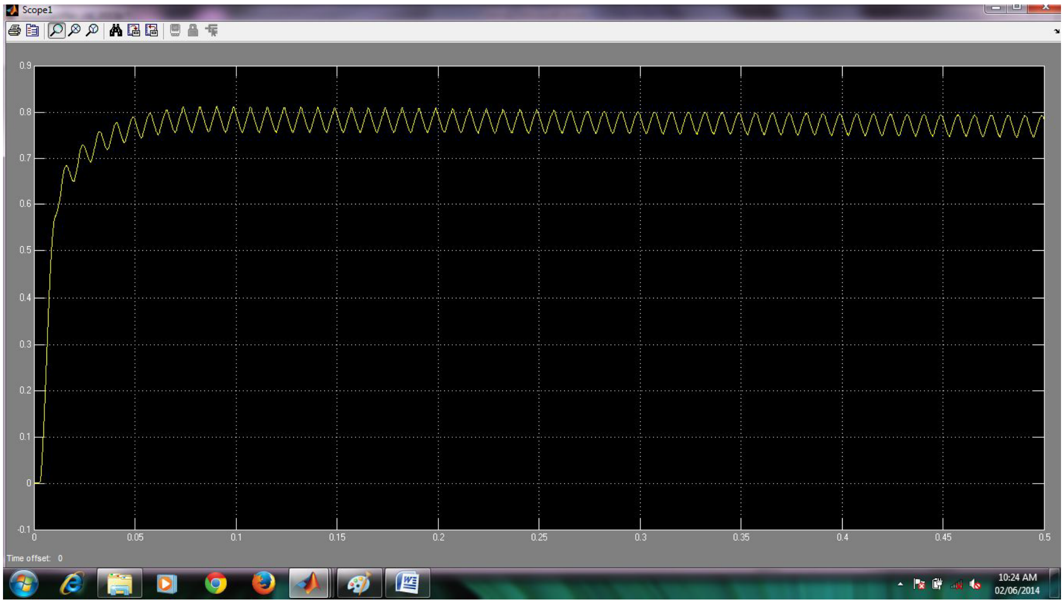

Fig 5.4 c) Output Current wave form at 250 ohms load.

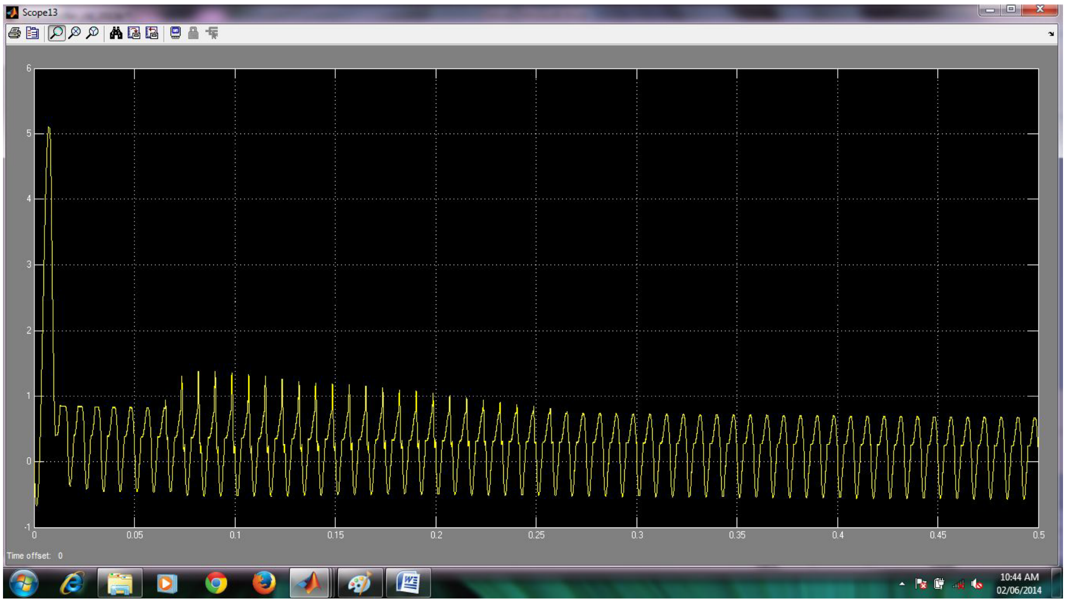

Fig 5.4 d) Current Error at 250 ohms loads.

The large reactance of the input inductor gives rise to significant low-frequency distortion, although it suppresses the input current ripple. Above figure shows the simulated input current waveforms near a zero-crossing when the input inductors are 1.4, 2.8 and 70mH, which limit the current ripple.

VI. CONCLUSION

From all the methods except PWM and SDM are the best suitable methods from which supply side waveform distortion can be reduced. But to get the optimum result SDM is the acceptable technique.

1. In conventional rectifiers from the analysis the known fact is, the output voltage is not regulated and also it is not constant at the output. This is because of non- linear load.
2. The method which used to overcome the above problem is sigma delta modulation in which output voltage is regulated and also constant at the output.
3. From these two techniques sigma delta modulation is an optimal method to overcome supply side distortion.
4. According to the obtained results it can be concluded that it is worth to continue developing new techniques i.e. sigma delta modulation to overcome supply side distortion.

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