Chapter - 1

Introduction

1.1 Introduction:

The power supplies based on linear series-pass regulated design is bulky, inefficient and obsolete for most of today’s applications. Moreover, the demand for improvement in efficiency and power to volume ratio with improved performance power supplies, have demanded the development in power electronics leading to modern sophisticated switch-mode power supplies (SMPS). The high frequency switching power supply meets these demands, and recently it has become the prime powering source in the majority of modern electronic designs. In recent years, following advancements in power semiconductors, control circuits and passive components, the switch-mode power supply (SMPS) has become very popular due to increased reliability and cost-effective.

1.2 The Off-Line Switch-Mode Power Supply (SMPS):

The off-line switch-mode power supply may be of many designs, such as half-bridge, flyback or forward, depending mainly on some factors such as cost, performance, power, application and designer’s choice. Irrespective of the converter topology, the basic building blocks of a SMPS are the same and shown in Fig. 1.1. The ac line voltage is directly rectified and filtered to produce unregulated dc. This dc is fed to a switching element i.e. transistor, MOSFET, IGBT etc, where it is chopped to a high frequency (above 20 KHz) pulse train. The resulting pulses are fed to an isolation transformer and the secondary voltage is rectified and filtered to produce the dc output. In order to regulate the output and keep it constant, irrespective of the changes in the input ac line or the
output load, a portion of the output voltage is monitored and fed back to a control logic circuit. The control circuit compares this output dc voltage to a reference and adjusts the conduction period of the switching element to control the width of the pulses, thereby regulating the output. A radio frequency interference (RFI) filter is also provided in the ac line to reduce high frequency disturbance (arising out of high frequency switching) to acceptable levels.

### 1.3 Types of Power Converters:

Any type of converter circuits can be related to one of the three classical circuits; such as buck, buck-boost and buck derived converters or an isolated version of buck, buck-boost or buck derived converters. If an isolation transformer is provided between input line and output load then the same converters are called forward, flyback and push-pull converters respectively.

![Fig. 1.1 Functional Block Diagram of an Off-Line SMPS.](image)
In a buck-boost converter, energy is stored in an inductor during the ON-period of the switch. This energy is transferred to the load during the OFF-period of the switch. Thus both input and output currents are pulsating in nature. In this converter, the output voltage is usually of opposite polarity to that of input.

In a buck converter, when the switch is closed, the input current flows to the output through a series inductor. When the switch is open, the energy stored in the inductor maintains the load current through a free-wheeling diode. Hence, in the converter, although input current is pulsating, output current is continuous, thus reducing the requirement of output filter size. Moreover, the output voltage is with same polarity as the input.

The buck derived or push-pull converter in reality consists of two forward converters operating in push-pull action, with alternate closing and opening of two switches. The main disadvantages of this circuit are higher switch voltage stress and unbalance volt-sec integral of each switching transistor leading to residual dc core saturation.

The above mentioned problems may be alleviated by using half bridge or full bridge converters. The half bridge power converter uses a center tap source and two series connected switches across the source. The power transformer is connected between the junction of the switches and the center point of the source. Any asymmetry in the split voltage source can also result in residual dc core saturation. However, a series capacitor will block the dc current flow through the transformer while its impedance at the high frequency will not significantly block ac currents. The full-bridge power converter uses two parallel branches of two series connected switches. The power transformer is
connected between the junctions of the switches of two parallel branches. Thus the requirement of center tap source is avoided.

1.4 **Soft-Switching:**

Soft-switching, also called quasi-resonant switching is an intermediate technique between pulse width modulation and resonant switching. In resonant switching converters, both current and voltage waveforms of a power switch are sinusoidal for the full operating cycle. Switching occurs when the voltage and/or current pass through zero. In soft-switching converter, a resonant tank circuit is activated only during switching intervals, such that the switch transition takes place when the voltage across the switch is zero (zero voltage switching) and/or when the current through the switch is zero (zero current switching). However, for the rest of period the circuit behaves as a normal PWM converter. This way the advantages of both the techniques are obtained to get reduced switching loss, reduced switching stress, low EMI and RFI, as well as constant frequency operation.

1.5 **Objective of the Present work:**

The scope of the research in present work can be understood, considering the simplified block diagram of a power supply as shown in Fig. 1.2. Here the dc/dc converter is used to provide a tightly regulated output voltage and eventually to provide galvanic isolation. Soft-switching PWM techniques are finding prime importance in recent years in the field of dc/dc converters. Phase-shifted PWM full bridge converter is also being studied and tested to be operated under soft-switched condition to obtain the advantages of
high efficiency, high power density, low EMI, even with constant frequency operation. Zero-voltage zero-current switched phase shift PWM full bridge converter can offer all the above mentioned advantages.

Nowadays, to comply with international standards, power factor correction has become almost mandatory in every power conversion equipment. The power factor correction is performed by a high frequency switching dc/dc converter, which forces the input current to become as close as possible to the line voltage. Thus, the equipment connected to the line behaves like a resistive load.

In this work, a hybrid ZV-ZCS phase-shift full bridge converter is proposed, which uses MOSFETs and IGBTs for different legs instead of four IGBTs as used in conventional converters. The proposed converter has been designed and simulated thoroughly to investigate the performance. To get the actual performance, an experimental laboratory prototype has been fabricated and voltage & current oscillograms have been captured at different points to verify its performance.

In this work, three new fully soft-switched boost power-factor correction circuits have been proposed. Out of these three, one circuit uses three power switches and other two circuits use two power switches operated with non-isolated gate drives. The proposed converter circuits have been designed and simulated thoroughly. Laboratory prototypes of the two switch converters have been fabricated for experimental verification. Detailed simulated results and experimental oscillograms have also been presented in this work.
1.6 **Organisation of the Thesis:**

The work embodied in this dissertation is organised as given below:

In Chapter-2, a detailed overview of previous work in the field of soft-switched phase-shift PWM dc/dc converter and soft-switched boost power factor correction circuits have been presented.

In Chapter-3, a brief discussion of soft-switching techniques and operating principle of a phase-shift PWM dc/dc converter with zero voltage switching is presented. This chapter also discusses a high power-factor pre-regulator circuit with boost converter and average current mode control.

In Chapter-4, a new hybrid ZV-ZCS full-bridge phase-shift PWM dc/dc converter with operating principle is proposed. Design example and also the control circuitry along with driver circuit have been discussed in this chapter.

In Chapter-5, the simulated as well as experimental results of the hybrid converter, proposed in chapter-4 are presented in detail.

In Chapter-6, a new zero-current switched boost converter for power factor correction is proposed with detailed simulated results.
In Chapter-7, a new fully soft-switched boost converter for active power factor correction is proposed and analysed in detail. Its design considerations, control and drive circuitry are also presented in this chapter.

In Chapter-8, a modified version of the new fully soft-switched boost converter for active power factor correction is proposed and analysed in detail.

In Chapter-9, the simulated and experimental results of the converters proposed in chapter-7 and chapter-8 are presented.

Chapter-10 summarises the contributions of the work and gives suggestions for further research in this field.