1. INTRODUCTION

Photovoltaic (PV) sources are well established in the alternative energy market and the total capacity of PV arrays each year is growing at an average rate of 26% per annum [1]. Photovoltaics are still relatively expensive and continuing efforts are required to drive down the costs of the solar cells and the support equipment. Power conditioning elements such as inverters constitute a reasonable proportion of the system cost. The inverter costs close to 20% of the total cost in a standard grid interactive system [2]. As solar cell prices fall the balance of system costs become more significant. This thesis attempts to make a contribution to the development of the grid interactive inverter technology. Globally, the percentage of the grid interactive PV systems has increased from 29% in 1992 to 83% in 2004 of the total PV capacity installed among the 19 countries participating the International Energy Agency Photovoltaic Power Systems Program (IEA PVPS) [2]. This thesis concentrates on the study of the possible topologies based on the two-inductor boost converter, that suit the applications in the Module Integrated Converter (MIC) technology, one of the main streams in the grid interactive PV implementations.

It should be mentioned that the author had previously completed a Master of Engineering thesis dealing with the two-inductor boost converter [3]. During that study the basic resonant two-inductor boost converter topology was developed. It became clear during that study that much more could be done to develop the topology, our understanding of the topology and its application base. The thesis content is briefly reviewed below.

Chapter 2 provides the literature survey. First the advantages of the grid interactive PV systems over the stand alone PV systems are listed. Then, three popular arrangements for grid interactive PV systems are briefly discussed. Among these, it is shown that the MIC technology has the greatest potential in PV applications and figures of merits of the state-of-the-art MICs are presented. It is shown that MIC implementations with high frequency transformers can be classified into three topologies and their main advantages and disadvantages are briefly explained. A comprehensive set of the proposed converters are also listed for each MIC topology.

Chapter 3 presents the research opportunities for the two-inductor boost converter. First, the power balance issue in the MIC implementations is discussed. In order to deal with the 100-Hz power ripple in the MICs, three possible solutions for capacitive energy storage are considered in the MIC design. Then recent research interests in the two-inductor boost converter are summarised and possible variations of the two-inductor boost converter for the three MIC topologies are provided at the end of the chapter.

Chapter 4 concentrates on the study of the soft-switched two-inductor boost converter as a dc-dc conversion stage in a MIC with an intermediate constant dc link. By varying the three circuit parameters in the resonant two-inductor boost converter, a wide load range can be achieved under the variable frequency control while the resonant condition can be maintained. In order to obtain a wider load range without the penalty of the high switch voltage stress, a soft-switched two-inductor boost converter with the voltage clamp is also developed. In both of the converters, the sets of the design equations and the control functions are explicitly established. Finally in the chapter, the power loss components in the soft-switched two-inductor boost converter are investigated. Under a specified load condition, the power loss in the converter varies with different circuit parameters and the set of the variable loss components are identified. In order to minimise the power loss in the soft-switched two-inductor boost converter, an optimised operating point can be numerically established.

Although the two-inductor boost topology has many advantages over other boost topologies, one significant disadvantage of this topology is the requirement of the three separate magnetic devices. Therefore, Chapter 5 studies the magnetic integration solutions in the two-inductor boost converter. Four integrated magnetic structures can be developed using both of the magnetic core integration and the winding integration methods. All four integrated magnetic structures are thoroughly investigated in the hard-switched two-inductor boost converter applications and the equivalent input and transformer magnetising inductances, the dc gain, the dc and ac flux densities and the current ripples in the individual windings are solved. One specific integrated magnetic structure, which presents a potential high transformer leakage inductance, is applied to the soft-switched two-inductor boost converter and the converter operation is also discussed in detail.

Chapter 6 presents the current fed two-inductor boost converter as the dc-dc conversion stage in the MIC topologies with an unfolding stage. In both of the hard-switched and the soft-switched arrangements, a sinusoidally modulated two-phase synchronous buck converter functions as the current source to the two-inductor boost cell. The hard-switched current fed two-inductor boost converter features the integrated magnetics, the non-dissipative snubbers, the silicon carbide rectifiers and the electrically isolated optical MOSFET drivers to achieve an overall compact design with a high efficiency. Among these technologies, a detailed analysis is provided for different operation modes of the non-dissipative snubbers. In the soft-switched arrangement, the buck conversion and unfolding stages are the same as those in the hard-switched arrangement. In the two-inductor boost cell, an optimised operating point is employed to minimise the power loss in the boost stage converter. In order to reduce the drive power loss with the conventional gate drive circuit, a resonant transition gate drive circuit is developed for the two-inductor boost cell and a detailed analysis is also provided.

Chapter 7 develops the two-inductor boost converter with a frequency changer for the third MIC topology. In this arrangement, the rectification stage of the original two-inductor boost converter is removed and a frequency changer is utilised to convert the high frequency ac current directly to the ac voltage of the grid frequency. Besides the simplicity of the circuit arrangement and the reduced component count, a significant advantage of this converter is the constant power output achieved by a small non-polarised capacitor used in the load.

Chapter 8 provides the conclusions for the thesis. The thesis has made a significant contribution to the understanding of the two-inductor boost converter. Original contributions have been made in the analysis of the resonant version of the converter that was first proposed by the author during his Master of Engineering studies. A new resonant transition gate drive circuit is presented for this topology. An extensive study has been made of loss optimised current fed resonant converter cells and of current fed hard-switched cells with non-dissipative snubbers. Novel contributions have also been made in the integrated magnetics of the converter and in the development of a frequency-changer-based MIC topology.

The conclusion also points out that the resonant converter approaches can be readily extended to variations of the two-inductor boost converter proposed by other researchers. This is a promising area of future research.