CHAPTER 1

INTRODUCTION

1.1 GENERAL

Power electronics is the branch of electrical engineering related to the use of semiconductor devices to convert power from the available source to the load requirement. The dynamic response problems are occurring in Alternative Current (AC) - Direct Current (DC) converters. Due to input power variation in Power Factor Correction (PFC) converters, output load voltage contains a ripple voltage, whose frequency is twice the line frequency, which affects the input current waveform unless the voltage loop bandwidth is held below the half of the line frequency. This low bandwidth in voltage loop makes the active PFC converters to have sluggish transient response. This sluggish transient response problem is further compounded by large voltage overshots and voltage drops enforcing additional stress on the PFC components, as well as on its downstream switch mode power supply load. The simple way of obtaining good transient response is possible only by sacrificing the efficiency of the overall system by cascading the PFC pre-regulator with second DC-DC converter.

Nowadays it is necessary to reduce the cost and increase the efficiency to make solar energy to be more attractive. The aim of this research is to develop an efficient photovoltaic model with Paralleled Boost Converter (PBC) based Maximum Power Point Tracking (MPPT) technique to track maximum power. DC-DC conversion technology was established in the year
of 1920. A simplest way of converting the DC-DC voltage is to produce the load voltage smaller than the supply voltage with reduced performance. In industrial applications, DC-DC conversion process is done by means of the multi-quadrant chopper which was presented by Rashid (1988). Due to the rapid development of communication technology, low voltage DC power supplies are required resulting in the expansion of DC-DC conversion technique. Choppers can be used to derive the prototype techniques by Mohan & Undeland (2007). The choppers are constructed by using semiconductors, which converts the fixed DC voltage magnitude into the variable DC voltage magnitude or Pulse Width Modulated (PWM) AC voltage.

1.2 LITERATURE SURVEY

Silva Ortigoza et al (2012) proposed the boost converter topology in various AC-DC and DC-AC applications. Everts et al (2012) presented an isolated AC-DC converter which frequently employed in service interfaced systems such as power supplies in telecommunication and data centers, plug-in hybrid electrical vehicles and battery operated electric vehicles. Mohan & Undeland (2007) stated that switching frequency should be increased by decreasing switching losses to achieve higher power density and faster transient response in well known PWM DC-DC converters. Singh et al (2003) proposed various AC-DC converters and listed its drawbacks of poor power quality in terms of injected current harmonics, which cause voltage distortion and poor power factor at input AC mains and slow varying ripples at DC output load, low efficiency and large size of AC and DC filters.

Salmon (1993) presented an active PFC technique, using a boost converter which has been successfully implemented to improve the power factor and reduce input current distortion in single-phase line current rectification. A near unity power factor and very low harmonic distortion along with good output voltage regulation can be achieved. Zero Voltage
Switching (ZVS) or Zero Current Switching (ZCS) was used to create soft switching in conventional PWM converters using auxiliary circuits. Due to the complexity of power flow in bidirectional converters, it is desirable to use an auxiliary circuit to provide soft switching in both power flow directions (buck and boost mode). In the bidirectional converters, two auxiliary circuits were employed to achieve soft switching when the power flows in both directions as presented by Bodur & Bakan (2002; 2004). Ahmadi et al. (2010) proposed the use of different types of switches for each direction of power flow.

The additional number of components can cause more conduction losses, along with increased complexity, cost, weight, and size of the converter. Sanchis-Kilders et al. (2006) proposed two auxiliary switches and single inductor type converter. This causes the auxiliary switches to operate under hard switching conditions, thus reducing the gain in overall efficiency achieved by the soft switching of the main switches. A ZVS buck-boost converter with ZVS for all converter switches needs two auxiliary switches proposed by Yan et al. (2002).

PWM DC-DC full-bridge converters with soft-switching are mostly used in industry. For lower power applications, where the converters are done with Metal Oxide Semiconductor Field Effect Transistor (MOSFET), ZVS techniques were used to improve the efficiency of the full-bridge converter as presented by Xu et al. (2005), McGrath et al. (2007) and Jin et al. (2010). For higher power applications, Insulated Gate Bi-polar Transistor (IGBT) are the preferred devices as they have lower conduction losses than MOSFET due to their fixed collector-emitter voltage drop and ZCS techniques. This is because ZCS methods can significantly reduce the tail in the IGBT device current that appears when the device is turned off. Reducing this current tail helps an IGBT operate with fewer turn-off losses and allows it to operate at higher
switching frequencies. Auxiliary circuits with two auxiliary switches are proposed by Wang et al (2009), Jin & Ruan (2006) to achieve ZCS for the main switches, but the increased cost of having two auxiliary circuits is a key drawback of these converters.

The use of active auxiliary circuits is avoided in converters as proposed by Huang (2007), where passive auxiliary snubber circuits with integrated magnetics were added to provide a soft turn-OFF for the main power switches. Although the use of multiple auxiliary switches is avoided with these converters, the passive circuits themselves can be quite sophisticated and the overall converter efficiency is lower than that of the above-mentioned converters that use multiple auxiliary switches. Chen et al (1999) developed the modified Positive Output Luo Converter (POLC) using the VLT for DC-DC converters, which suppressed the auxiliary switch in the original POLC to perform the similar functions. It gives good output voltage with constant ripples and can be applied in high voltage projects.

Simulation verification and design of Proportional Integral Derivative (PID) controller and Fuzzy Logic Controller (FLC) for paralleled negative output elementary luo converter using computer simulation was presented by Kayalvizhi et al (2005). Design of FLC for paralleled Positive Output Elementary Luo Converter (POELC) using MATLAB/Simulink was presented by Kayalvizhi et al (2006). However, the authors analyzed only the line and load variation of the same converter using the Proportional Integral (PI) and the FLC.

The experimental analysis of bifurcation in hysteresis current programmed control for POELC was reported by Kavitha & Uma (2007). Zhu & Luo (2007) introduced the theoretical, simulation and experimental implementation by utilizing the Voltage Lift Technique (VLT) for development of Single Ended Primary Inductance Converter (SEPIC) and
Cuk converters. The PI controller for double output elementary LC was presented by Basanth et al (2009), but the output voltage response of the same converter using the PI controller produces more overshoots (around 15V) in line as well as load variations. A series of negative output DC-DC converters voltage-lift-type Cuk converters was introduced by Zhu & Luo (2009). The step-up DC-DC converter through the coupled inductor and the VLT was presented by Changchien et al (2010). This converter used to achieve the high step-up voltage gain. The generalized modeling and design of SMC for triple lift Luo Converter (LC) using Super-Lift Technique (SLT) has been well presented by Jiao et al (2011). The PI controller for positive super lift LC using solar panel power system has been reported by Shan et al (2012). However the transient region of this converter using the designed controller produces the huge overshoots.

Another method to improve the efficiency of DC-DC PWM full-bridge converters is to implement them with auxiliary circuits that cause them to operate with Zero-Voltage-Zero-Current-Switching (ZVZCS). These converters either use a secondary-side auxiliary switch Seok & Kwon (2001), Liu et al (2010) or a secondary-side passive circuit Cho et al (2000), Song & Huang (2005), Wu et al (2008) to create a counter voltage in the converter primary that helps extinguish the current that would otherwise circulate in the full-bridge whenever the converter is in a freewheeling mode and do nothing but create conduction losses. Regardless of what method is used to extinguish the freewheeling current, ZVZCS converters allow only their lagging leg switches to operate with ZCS so that IGBT cannot be used in their leading leg. This forces the use of MOSFET in this leg instead of IGBT to avoid high current losses at turn-OFF and intern increases the cost of the converters as two different types of devices must be used as the main power switches in the converter.
1.2.1 Review of Boost Converter for Solar PV

Solar Photovoltaic (PV) power is an untapped source of energy and holds more research to make it reliable and efficient. One approach to understand and improve solar PV system efficiency is digital modeling and simulation. After successfully modeling and simulating solar PV module, it is possible to develop methods to improve system performance. Walker (2001) developed an accurate model for solar PV module using Shockley diode equation. The simple model has a photo-current source, a single diode junction and a series resistance, and includes temperature dependences. The model was used to investigate the variation of MPP with temperature and insolation levels. The buck versus boost MPPT topology was made and compared with a direct constant voltage (battery) load. The method of parameter extraction and model evaluation in MATLAB/Simulink was demonstrated for a typical 60W solar panel.

Gow & Manning (1999) developed a general model for solar PV module which can be implemented on simulation platform such as PSPICE or SABER. The model accepts irradiance and temperature as variable parameters and gives I-V characteristics for the particular PV cell as output. Kawamura et al (2003) investigated the relation between the output lowering due to shaded PV cells and the change of I-V characteristics using computer simulation. It was proven from the simulation that I-V characteristics were changed by the condition of the shadow, which covered the module. The change of I-V characteristics of a PV module with shaded PV cells was discussed.

Quaschning & Hanitsch (1996) developed a model to describe the relationship between current and voltage of a solar cell in generation region as well as the breakdowns at positive and negative voltages. They described a set of suitable numerical algorithms to compute the currents for a given voltage at the solar cell and vice versa. Villalva & Gazoli (2009) proposed a method of
modeling and simulation of PV arrays. The main objective was to find the parameters of the nonlinear I-V equation by adjusting the curve at three points: open circuit, maximum power and short circuit. Given these three points, which are provided by all commercial array datasheets, the method finds the best I–V equation for the single-diode PV model, including the effect of the series and parallel resistances and warranties that the maximum power of the model matches with the maximum power of the real array. With the parameters of the adjusted I-V equation, one can build a PV circuit model with any circuit simulator by using basic math blocks.

The Maximum Power Point (MPP) is an operating point of solar PV at which it can deliver maximum power to the load. To predict the MPP, many tracking algorithms are available. Esram & Chapman (2007) discussed several techniques for MPPT of PV arrays. They showed that at least nineteen distinct methods have been introduced in the literature, with many variations on implementation. Their work has served as a convenient reference for future work in PV power generation. Different MPPT techniques discussed earlier will suit different applications. For example, in space satellites and orbital stations that involve a large amount of money, the cost and complexity of the MPP tracker are not as important as its performance and reliability. The tracker should be able to continuously track the true MPP in minimum amount of time and should not require periodic tuning. In this case, Hill climbing/PAO, IncCond and RCC are appropriate.

MPPT techniques applied to single-stage, grid-connected PV systems are compared by Jain & Agarwal (2007). MPP techniques are compared on the basis of the time taken to reach (track) the MPP, operating point oscillations in the vicinity of MPP and the dependence of the algorithms, if any, on array configuration and parameters. Comparison was
also made on the basis of the energy extracted from the PV source during the transient tracking phase.

Liu et al (2008) employed variable step size incremental conductance MPPT technique in PV systems to make full utilization of PV array output power which automatically adjusts the step size to track the PV array MPP. The MPPT speed and accuracy are improved. Different from the traditional MPPT approaches, the Takagi Sugeno (TS) fuzzy controller directly drives the system to the MPP without searching the MPP and measuring insolation. Chiu (2010) presented MPPT control for stand-alone solar power generation systems via the (TS) fuzzy-model-based approach.

Kottas et al (2006) presented MPPT using fuzzy set theory to improve energy conversion efficiency. The maximum power operation of any PV array under different conditions such as changing insolation and temperature was discussed with fuzzy cognitive network.

To have faster dynamics and improved stability when compared to the traditional PAO, Piegari & Rizzo (2010), Yang & Zhao (2011) proposed Adaptive Perturb And Observer (APAO) method. The APAO MPPT algorithm was set up and validated by means of numerical simulations and experimental tests, confirming the effectiveness of the method. The authors also discussed the main aspects of the MPPT techniques to be taken into the consideration.

A new MPPT system, consisting of a buck-type DC-DC converter, which is controlled by a microcontroller-based unit was proposed by Tung et al (2006). The main difference between the method used in the proposed MPPT system and other techniques used in the past is that the PV array output power is used to directly control the DC-DC converter, thus reducing the complexity of the system. The resulting system has high-efficiency, lower-
cost and can easily be modified to handle more energy sources. Jiang et al (2005) developed a novel three-point weight comparison method that avoids the oscillation problem of the Perturbation And Observation (PAO) algorithm which is often employed to track the MPP. Furthermore, a low cost control unit is developed, based on a single chip to adjust the output voltage of the solar cell array.

The experimental way to measure the I–V characteristic curve of PV generators based on DC-DC converters was proposed by Durán et al (2009). The obtained results show that the classical buck and boost converters are not capable of reproducing the whole I–V curve of PV generators. The SEpic and Cuk converter are good choices for this application. Walker & Sernia (2004) proposed an alternative topology of non-isolated per-panel DC-DC converters connected in a series to create high voltage string, connected to a simplified DC–AC inverter buck, boost, buck-boost and Cuk converters. MATLAB simulations are used to compare the efficiency of each topology as well as evaluating the benefits of increasing cost and complexity. The buck and boost converters are shown to be the most efficient topologies for a given cost, with the buck best suited for long strings and the boost for short strings.

Enslin et al (1997) proposed a low-power low-cost highly efficient MPPT to be integrated into a PV panel. This integrated MPPT uses a simple controller in order to be cost effective. Furthermore, the converter has to be very efficient in order to transfer more energy to the load than a directly coupled system. This is achieved by using a simple Soft Switching (SS) topology. The higher conversion efficiency at lower cost will result in making the MPPT an affordable solution for small PV energy systems. Lim & Hamill (2000) presented MPPT for solar arrays using DC-DC converter. The MPPT system comprises a solar array, a buck DC-DC converter feeding a battery and a controller.
Tse et al (2004), Chung et al (2003) developed a novel technique for efficiently extracting maximum power from PV panels. A SEPIC or Cuk converter operating in discontinuous inductor current or capacitor voltage mode is used to match with the output resistance of the panel. By injecting the switching frequency with a small signal sinusoidal variation and comparing the maximum variation and the average value at the input voltage, the MPP can be located. This method is simple and elegant without requiring any digital computation and approximation of the panel characteristics. The nominal duty cycle of the main switch in the converter is adjusted to a value, so that the input resistance of the converter is equal to the equivalent output resistance of the solar panel at the MPP. \( V^2 \)-based MPPT scheme using a SEPIC converter topology was discussed by Veerachary (2005). For a given solar insolation, the tracking algorithm changes the duty ratio of the converter such that the solar PV voltage equals the voltage corresponding to the MPP. This is done by the tracking algorithm, which mainly computes the power proportional to square of terminal voltage and changes the duty ratio of the converter so that this power is maximum.

Chiang et al (2009) developed a modeling and controller design of the PV charger system implemented with the SEPIC converter. The control objective is to balance the power flow from the PV module to the battery and the load such that the PV power is utilized effectively and the battery is charged with three charging stages. Snyman & Enslin (1993) evaluated MPPT converters using some basic power components. The parallel power conversion technique is used to enhance the energy conversion efficiency in the PV system.

Bennett et al (2012) compared different converter topologies with solar PV model which was developed by removing the series and/or parallel resistors. The models were expected to yield similar results due to the large
parallel resistance and small series resistance to see if the dynamic behavior of the PV system depended on the converter used. Algazar et al (2012) proposed a new technique for MPPT for standalone PV system. A FLC was applied to a DC-DC converter to extract maximum power increase the efficiency of energy production from solar PV.

Wu et al (2008) proposed a boost converter with coupled inductors and a buck–boost type of active clamp. In the converter, the active-clamp circuit is used to eliminate the voltage spike that is induced by the trapped energy in the leakage inductor of the coupled inductors. The active switch in the converter can still sustain a proper duty ratio even under high step-up applications, reducing voltage and current stresses significantly. Since both main and auxiliary switches can be turned on with ZVS, switching loss can be reduced and conversion efficiency can be improved significantly.

Costa & Duarte (2004) developed a Cuk converter featuring clamping action, PWM and SS commutation. The SS commutation was proposed to overcome the limitations of the conventional Cuk converter. Duarte & Barbi (1997) presented a technique to generate a complete family of two-switch PWM with active clamping DC-DC converters, featuring soft commutation of the semiconductors at zero voltage. Lin & Huang (1997) proposed ZCS Cuk converter in order to achieve power factor of unity, less harmonic control contents, zero switch loss, simpler control stage, higher power density and unidirectional power flow. Optional principles, design analysis, small signal models and conditions achieving zero switching loss for the proposed converter are described.

The regulation of the output voltage of PV arrays was analyzed by Villalva et al (2010). DC-DC buck converter is used as an interface between the PV array and the load. The input voltage of the converter is controlled in order to regulate the operating point of the array. Besides reducing losses and
stress because of the bandwidth-limited regulation of the converter duty cycle, controlling the converter input voltage reduces the settling time and avoids oscillation and overshoot, making easier the functioning of MPPT methods.

Xiao et al (2007) discussed the use of youla parameterization to design a stable control system for regulating the PV voltage. In photovoltaic power systems, both PV modules and switching mode converters present non-linear and time-variant characteristics, which result in a difficult control problem. Iqbal et al (2007) investigated the existence of non linear sub-harmonic oscillations, quasi-periodicity, bifurcations and chaos in buck, boost converters. di Bernardo et al (1998) analyzed non-linear phenomena in closed-loop PWM DC-DC converters. The authors introduced a non-linear switching map which is related to synchronous switching. The author proposed a possible explanation of the sudden jump to chaos exhibited by DC-DC converters.

Zhou & Li (2012) studied chaos in three typical topology power electronic converters with a close loop controller. They discussed the existing methods to control chaos and analyzed the features. The design of analogue chaotic carrier, which can be used in PWM DC-DC converters to reduce Electromagnetic Interference (EMI), was proposed by Li et al (2010). The designed chaotic carrier is simpler and much cheaper than a corresponding digital implementation. Morgul (1995) developed a chaotic oscillator circuits to generate the chaotic signals by coupling chua diode with Wien bridge oscillator in parallel. The designed chaotic carrier is simpler and much cheaper than a corresponding digital implementation. According to the simulation and experimental results obtained, the analogue chaotic carrier can greatly suppress EMI of DC-DC converters while the other characteristics of the boost converter are well maintained.
Ma et al (2012) discussed sampled-data model and applied it to analyze the dynamics of Cuk converter. The results show that the four eigen values of the converter can be two pairs of complex conjugates and that one pair may move out of the unit circle as some parameters are varied. This causes occurrence of slow-scale oscillation as a result of the Neimark–Sacker bifurcation in the input stage of the converter. A washout filter is used to control the bifurcation so as to stabilize the converter, and the effects of parameters of the filter on the stability of the converter are analyzed.

The chaotic behavior in current mode controlled SEPIC converter operating in continuous conduction mode by varying the reference current was analyzed by Kavitha & Uma (2010). It was observed that the system changes from a stable buck-like operation to an unstable boost-like operation by varying reference current. Bifurcation diagram was plotted for control signal and capacitor voltage with reference current as bifurcation parameter. Resonant parametric perturbation control technique was applied to suppress chaos. Effects of phase shift and frequency mismatch were also analyzed.

Poddar et al (1998) demonstrated that DC–DC buck and boost converters with current or voltage feedback exhibit chaos for significantly large ranges of parameter values. The authors presented two methods for controlling chaos which are particularly suitable for switching circuits. The results of numerical investigation and experimental implementation were presented with reference to the duty cycle controlled buck converter. Kavitha & Uma (2008) analyzed the bifurcations in current-controlled Luo topology, operating in Continuous Conduction Mode (CCM) using continuous-time model. The stability of the system was analyzed by studying the locus of the complex eigen values, and the characteristic multipliers locate the onset of Hopf bifurcation. The 1-periodic orbit lost its stability via Hopf bifurcation and the resulting attractor is a quasi-periodic orbit.
Cafagna & Grassi (2005) illustrated an experimental study of a current-programmed DC-DC boost converter, with the aim of investigating possible pathways through which the converter may enter chaos. In particular, based on experimental measurements, it is shown that variations of input voltage and reference current can generate periodic, sub-harmonic, quasi-periodic and chaotic behaviors. Yinghua et al (2012) attempted to reduce the electromagnetic interference of traditional PWM inverter using SS PWM inverter. The EMI conductive noise of AC inverter system was measured, analyzed and compared under Hard Switching (HS) and SS respectively.

1.2.2 Reviews of SMC for DC-DC Converters

The preliminary design aspects and demonstration of SMC for DC-DC buck converter has been well reported by Bilalovi et al (1983). The complete description of SMC applied for various topologies of second order DC-DC converters and also the methodology of relating the equivalent control technique of SMC theory to the duty ratio control method of PWM technique to achieve constant frequency SMC have been presented by Venkataraman et al (1985). Experimental specification of SMC for complex forth-order Cuk converter has been introduced by Huang et al (1989). Malesani et al (1995) proposed a new approach to the design and implementation of SMC for valid reduced second order Cuk power converter. This novel approach ensured the excellent static and dynamic performances. The major benefits of this proposed approach are a simple control implementation, large-signal stability, no oscillatory response of all state variables and little settling time.

Mattavelli et al (1993) presented a general-purpose SMC, which can be used in the most DC-DC power converter topologies and it shows that the control circuit has the same circuit difficulty as standard Current Mode Control (CMC), but it provided tremendous robustness and speed of response
against line, load and parameter variations. In addition, different to other sliding-mode techniques, the proposed solution features the fixed operating frequency in steady state, synchronization to external triggers and non-appearance of steady-state errors in the load voltage. The computer simulation and experimental evaluation of the closed-loop operation of output voltage regulation for ZCS though the SMC has been introduced by Im et al (1994). The complete analysis, design and experimental description of PWM rectifier, which includes an uncontrolled rectifier and a Cuk converter stage driven by using a SMC has been reported by Rossetto et al (1994).

The analysis design, simulation and experimental verification of small-signal model of DC-DC converters using SMC have been introduced by Mattavelli et al (1995). Mahdavi et al (1997), projected the state space averaging method to PWM based SMC various types of DC-DC converters with fixed switching frequency. Lopez et al (1998) introduced a novel approach to design and analysis of a paralleled DC-DC buck converter using a multi-input SMC. This approach is based on sliding surfaces that obviously provide interleaving between the cells of a modular power supply plant. The experimental validation of different type non-linear controllers for switching power converters has been presented by Escobar et al (1999). The overall design examination of EMI quandaries in switch mode power supply has been well presented by Vilathgamuwa et al (1999).

Castilla et al (2000) generated a new design method of SMC technique for quantum resonant DC-DC converters. However, this method is based on the burden of a particular output voltage dynamic response and it provides a set of sliding surfaces guaranteeing large robustness and high signal stability. Orosco & Vazquez (2000) developed a complete general-purpose analysis of discrete SMC for DC-DC buck converter and this analysis includes the reaching condition, the evidence of the existence condition of the
sliding mode and stability condition. Further, Mahdavi et al (2000) has applied neural networks into their PWM based SMC for various types of DC-DC converter. The design and experimental verification of a master-slave SMC for a modular inverter plant composed of N-parallel connected buck-based single phase inverters has been reported by Ramos et al (2001).

Non minimum phase tracking control is reduced to a state tracking problem for boost and buck-boost power converters through the stable system centre has been presented by Shtessel et al (2003). The load voltage regulation of boost converter using generalized PI cum SMC has been addressed by Sira-Ramirez (2003). Ahmed et al (2003) presented an experimental analysis of SMC for DC-DC buck converter. They also demonstrated the implementation of the SMC for DC-DC buck-boost converter using control desk dSPACE software. The analysis and design of a paralleled DC-DC converter operation using SMC and this design is particularized for a system that consists of boost converter and a PI controller based current feedback loop of the output voltage error has been well executed by Lopez et al (2004).

Experimental development and frequency domain analysis of SMC using fractional order model for buck converter in comparison with PI controller at line and load variations has been presented by Calderon et al (2006). Tan et al (2007) presented various issues on the design and practical implementation of a PWM based SMC for buck, buck-boost converter operated in CCM. The non-linear control of switched-capacitor converters using SMC approach has been presented by Tan et al (2008). The systematic step-by-step design of fuzzy PID approach for boost converter through the simulation in voltage mode as well as in CMC has been investigated by Guesmi et al (2008). The sustained slow-scale oscillation in higher order CMC converter has been dealt by Wong et al (2008).
He et al (2010) proposes the analysis and simulation validation of new technique for SMC of DC-DC buck converter with fixed frequency. Theory, model and simulation of dynamic control for synchronous buck DC-DC converter using MATLAB/Simulink has investigated by Ahmed Saudi Samosir & Abdul Halim Mohd Yatim (2010). Experimental verification of FLC cum SMC for boost converter in comparison with linear PID and PI controller at various operating conditions has been executed by Guo et al (2011).

Design of Classical first order and higher order SMC for the attitude stabilization of a four rotor helicopter has been addressed by Bouchoucha et al (2011). However this classical SMC is used to control the roll, pitch and yaw angles of the helicopter. Comments on some of the simulated results in design of practical SMC with fixed switching frequency for DC-DC boost converters. A variable structure approach is applied to design and tune a FLC for a boost DC-DC converter and also the quantity of time needed for design and tuning is greatly reduced through the variable structure approach has been reported by Guo et al (2012).

Experimental and simulation validation of adaptive terminal SMC for DC-DC buck converter in comparisons with SMC has been reported by Komurcugil (2012). Modeling and implementation of FLC and PID for DC-DC synchronous buck converter under the line and load variation has been presented by Augusti Lindiya & Palani Iyyappan (2012). The average generalized PI output feedback regulator as a steer for defining the switched implementation of the average sliding mode features through a sigma-delta modulation strategy has been addressed by Sira-Ramirez et al (2013). Field Programmable Gate Array based design of SMC for four-phase buck converters have been presented by Romos et al (2013). Sliding mode and fault
tolerant control for multi-cell converter through the simulation was analyzed by Maradi et al (2013).

The earlier attempts in implementation of SMC for DC-DC converters suffer due to higher system order and hence increased complexity caused by more number of sensors. The optimal possible reductions in the performance indices such as peak over shoot, steady state error etc. could only achieved by adding/changing controller than tuning the conventional PID. The archived double integral controllers are of fixed switching schemes and implemented in indirect way. Corroboration of the performance enhanced controllers like double integral controllers has straight forward logic only in analog platform rather than in digital systems.

1.3 OBJECTIVES OF THE THESIS

The main objectives of the research work are as follows:

- To model the parallel boost converter with active snubber module in MATLAB/Simulink and study the modes of operation.
- To analyze and simulate the power factor correction of parallel boost converter.
- To analyze and simulate the solar photovoltaic based parallel boost converter.
- To design and implement a sliding mode controller for voltage control in parallel boost converter.
- To design prototype model to perform and comparative analysis
1.4 ORGANIZATION OF THESIS

The thesis is divided into seven chapters. The organization of the thesis is as follows:

**Chapter 1:** In this chapter, a brief introduction to the history of AC–DC & DC–DC converters, overviews of the BC are presented. A detailed survey of literature is also carried out on the various techniques for power factor correction, solar PV and control strategized for regulating the load voltage as well as current sharing in paralleled conventional DC–DC converters and BC with major problems. Also, the end of this chapter is clearly focused on the objective of the research work.

**Chapter 2:** The recent trends, technical aspects of converters, PV system and controllers are discussed.

**Chapter 3:** The analysis, operating modes and modeling concept for parallel boost converter with active snubber circuit is well addressed in this chapter.

**Chapter 4:** The concept of PBC with active snubber circuit operated in CCM is well addressed in this chapter. Also the simulation results of the PBC with active snubber for power factor correction results were discussed.

**Chapter 5:** The analysis and modeling concept of solar power based PBC operated in CCM is well addressed in this chapter. Also, the simulation results of the PBC with active snubber were discussed.

**Chapter 6:** This chapter presents the theoretical analysis, design, and mathematical modeling of POEPBC using SMC. The operating switching frequency range and its corresponding band width of the SMC is controlled by using the hysteresis relay. The SSAM for Positive Output Elementary Parallel Boost Converter (POEPBC) is obtained at early and then controller is
developed. The performance of POEPBC using the developed Hysteresis Modulation (HM) based SMC is validated at different operating regions in comparison study of classical linear Proportional Integral (PI) controller. Results are discussed in this chapter along with the complete design procedure.

Chapter 7: Finally, this chapter presents conclusion to the thesis by reiterating the major contributions as well as highlighted the feasible future work.

1.5 CONCLUSION

The literature review, objectives and organization of the thesis have been presented in this chapter.