CHAPTER 2

REVIEW OF LITERATURE

DC-DC converters play a significant role in power electronic circuits in various applications. Nowadays, DC-DC converters also play a vital role in the renewable energy system. Control of DC-DC converters decides their efficiency and performance.

2.1 DC-DC Converters

Ali Davoudi et al. [2006] developed a general approach for generating the state-space average-value models of PWM DC-DC Converters operating in Discontinuous Conduction Mode (DCM) and Continuous Conduction Mode (CCM). In this system, the so-called duty ratio constraint and the correction term (correction matrix extracted numerically to obtain a correct state-space) are extracted numerically and are expressed as nonlinear functions of the duty cycle and average value of the fast state variable (which responds for changes in controlling variable). The parasitic effects of circuit elements are readily included. The proposed numerically constructed model can function seamlessly in both CCM and DCM. The proposed system methodology overcomes the complexity and challenges common to many previously developed models when the parasitic of circuit elements are considered. The system result indicates that the proposed system model is to be very exact in predicting the large-signal time-domain transients as well as the small-signal frequency-domain characteristics. This system provides a convenient framework for systematically averaging the Pulse Width Modulation (PWM) DC-DC converters and raises new possibilities for future research in automated average-value modelling.
Pachauri et al. [2016] analyzed the modelling and simulation of PV fed Cuk, SEPIC, Zeta and Luo DC-DC converter. The system simulations are simulated as using MATLAB/ Simulink. In this system, four different converters are analyzed in normal, buck and boost modes of the converters. The converters are analyzed for various duty ratios for different modes with the constant resistive load. They found the performance of Zeta and Sepic converters as average, but concluded that the Cuk converter has highest transients and more settling time in comparison to all considered DC-DC boost converters. The system simulation result shows the Luo DC-DC converter is the best concerning transient response among all DC-DC boost converter.

Khattab H. A et al. [2016] discussed a system Design, Control and Performance Analysis of DC-DC Boost Converter for Stand-Alone PV System. They consider solar energy as one of the most reliable, daily available and environment-friendly renewable energy sources. Their system consists of a module of solar cells, a DC-DC boost converter with its duty cycle controller and load (resistive or dc motor). DC-DC converters are applied between the PV source of 12V and the load as power conditioning unit to regulate and boost up the photovoltaic voltage to desired output voltage. The duty cycle of the converter needs to be adjusted to obtain a constant level of voltage of 40V. This system is modelled and simulation was done in MATLAB/Simulink. In this system, Proportional-Integral (PI) and Fuzzy Logic Control (FLC) are used to control the duty cycle of DC/DC converter. In the fuzzy controller, fuzzy logic summarizes 25 rules of proposed control algorithm for getting better output of FLC controller. The system result shows FLC performs very well as it reduces the response time of settling voltage in the range of 1.25sec, reduces overshoot and has an advantage of fast response with higher accuracy comparing to PI controller.
Mahdi Salimi et al. [2016] designed robust closed loop control of the transformer less DC-DC converters with a high step-up voltage gain. In this system robust control of the high-gain DC-DC converters are investigated using Sliding Mode Controller (SMC) and the system has a right half plane zero in the converter transfer function. The proposed system output voltage is controlled by regulation of the inductor current. In the designed controller, control law includes integral of the output voltage error. Hence the proposed approach has no steady-state error. Using this converter, it is possible to apply the regulator in a wide range of operations. The proposed converter system is simulated in different operating conditions using MATLAB/Simulink toolbox. The Sliding Mode Controller (SMC) is designed based on fixed frequency equivalent control approach. The system voltage transfer function of the converter includes a right half plane zero and High Voltage Gain Converter (HVGC) is non-minimum phase system. This is solved by regulation of the inductor current of 3A in the other internal loop. The system result indicates the proposed HVGC system is completely stable and robust about large variations of the load value.

Subhransu Padhee et al. [2016] discussed classification of different DC-DC converter topologies used in Power Conditioning Unit (PCU) for a renewable energy source (fuel cell). A PCU which comprises different power electronic converters is essential to process the power of renewable energy sources and make them useable for a stand-alone or grid-tied application. In this paper, a comprehensive analysis is carried out for different non-isolated, isolated, soft switched and resonant converters used in PCU. Performances of SEPIC converter, ZVS converter, PWM converter and boost LLC converters are analyzed. The main advantage of soft switched topology is higher conversion ratio where boost converter operates in hard switching mode where LLC resonant converter operates in soft switching mode. The converter control is simple, and the regulated voltage at the DC-link can be up to 400V DC. In real time, reduction of the PCU cost, increase in fuel cell life cycle,
reliability and efficiency are some of the major challenges faced by the power electronics designer while designing a PCU. Therefore, this proposed analysis provides a classification of the DC-DC converter on the basis of conversion ratio as well as component count. Wide categories of the converter such as non isolated, isolated and soft switched converters are analyzed.

Guipeng Chen et al. [2017] designed magnetic coupling non-isolated bidirectional DC-DC converters using Zero-Voltage-Switching. The additional resonant inductor is eliminated, and magnetic core number is reduced. This system consists of thirteen variable Zero Voltage Switching (ZVS) topologies for obtaining an effective output of the system and can thus obtain a maximum output power of 500 W; the system can also achieve soft-switching operation in both power flow directions with a simple auxiliary circuit. The system result shows that in both buck and boost modes, the soft-switching operation of switches were achieved over wide load and voltage ranges, with maximum efficiencies. The proposed system topology derivation methodology can be easily extended to other bidirectional DC-DC converters.

2.2 Luo converter

Fang Lin Luo et al. [2003] developed a Voltage Lift (VL) Technique, a popular method widely used in electronic circuit design. It has been successfully employed in DC-DC converter with high voltage gain. Positive Output Super-Lift (POSL) Luo-Converters have been successfully developed and employed in some communication equipment. A negative output voltage is also obtained for some special usages. The author discussed a novel approach of Super Lift Technique that implements the output voltage increasing in geometric progression and it effectively enhances voltage transfer gain in power-law. To obtain the system design and calculation results, Pspice simulation package was applied to these converters. The
The proposed system can be sorted into two sub-series—one is Negative output main series, and another one is Negative output additional series. The system was constructed as the voltage of 20V and 100 kHz frequency. The system result shows that the system largely increases the voltage transfer gain in power series. The very high output voltage is easily obtained.

Hong Ye et al. [2004] presented Micro-power-consumption technique requires high power-density DC-DC converters and power supply source. A switched compact capacitor can be integrated into a power IC chip. Combining switched-capacitor and voltage, lift technique was used to construct DC-DC converters with small size, high power density, high-voltage transfer gain, high power efficiency, and low electromagnetic interference. The author discusses a new series of multiple-lift, push-pull switched capacitor DC-DC Luo converters that provide positive output. The system simulation was done by using Pspice simulation. The proposed system can be divided into two sub-series—one positive output main series, and another, positive output additional series. Eight lift and twelve lift circuits are simulated and experimentally analyzed. The system simulation results show a high voltage transfer gain and high output voltage. This series of DC-DC converters are suitable and convenient to be applied in industrial applications with the high output voltage.

He. Y et al. [2005] analyzed the voltage-lift technique by applying it to several series of DC-DC Luo converters. In this system analysis, four converters with voltage-lift circuit are analyzed. They are positive output self-lift Luo converter, positive output super-lift converter, negative output self-lift Luo converter, and positive output re-lift Luo converter. These converters are operated in both continuous and discontinuous conduction modes. The boundary between continuous and discontinuous conduction modes and the modified voltage transfer gain are derived for each circuit. The system result shows the Voltage Lift Converter (VLC) reduces the voltage transfer gain of
Luo converters under both CCM and DCM. Owing to the existence of VLC circuit, the load resistance and the switching frequency of the converter may also affect the VTG and boundary condition. These analyses have also been extended to series of Luo converters. Generalized equations are given for both positive output Luo converters and negative output Luo converters. These results will be useful in the design and modelling of such converters.

Dr. Fang Lin Luo et al. [2006] proposed a novel approach to Power Factor Correction (PFC). He designed a new inductor and used it in a AC/AC converter to measure PFC. AC/AC converters are traditionally implemented by Voltage regulation technique. However, they have high Total Harmonic Distortion (THD), Low Power Factor (PF) and poor power transfer efficiency (η). The proposed method implements DC-DC conversion technology into the AC/AC converters. The proposed DC-modulated Power Factor Correction on AC/AC Luo-Converter effectively improved the power factor up to PF = 0.99978 and the power transfer efficiency up to 97.8%. Experimental analysis was done for validating simulation analysis.

Tao Wang et al. [2012] analyzed the fundamentals of split-capacitors and split - inductors. In this system, the Positive output Luo-converter is taken as the platform by which the integration of split-capacitors/inductors with the voltage lift technique is implemented. The voltage transfer gains of the newly-derived DC-DC topologies are significantly increased along with the number increasing of split-capacitors and split- inductors. In a system, the self-lift circuit and multi-lift circuit of Luo converter are considered and analyzed with variable load. From the system case study on the Positive output Luo-converters, it is seen that the extended DC-DC topologies are featured with the very high voltage transfer gains and transformer less structures.
Ahmed Hammoda et al. [2014] discussed estimate and evaluation of the dc-dc converters based on energy factor and sub-sequential parameters. He has developed a two-stage positive output connecting boost and super lift converter. He also developed a mathematical model for power DC-DC converters (second order transfer function for any number of capacitors and inductors). The system simulations are done by using National Instrument (NI) Simulink. The system parameters are extracted and then compared with the results of NI MULTISIM modelling for a transient and steady-state period of the output voltage. The system result shows that the transient period, percentage overshoot oscillation, and efficiency are non-directly proportional to the resistance of the inductors, but at the same time the voltage drop of the output voltage is directly proportional to the resistance of the inductors. Practical results have not yet been demonstrated to verify the presented theoretical analysis.

2.3 Comparison of PI Controller with Modern Controllers in DC-DC Converter

Komurcugil [2004] designed PI-type Self-Tuning Fuzzy Control (STFC) strategy for a dc-dc boost converter. The STFC strategy tunes the output gain on-line by using an updating factor that is generated by using a second rule base. The tuning process is made according to the current trend of the controlled converter. The tuning fuzzy controller output gain is defined on error and change of error of the controlled variable using membership functions. In the fuzzy controller, fuzzy logic summarizes 49 rules of proposed control algorithm for getting the better output of FLC controller. The STFC system results are compared with the conventional Fuzzy Controller (FC) system concerning several performance measures such as overshoot and settling time. The proposed system simulation result indicates that the system has no steady-state error in the output voltage, no chattering problem, and a fixed switching frequency operation. The STFC depends neither on the converter being controlled nor on the controller used.
Deepak Renwal et al. [2015] have designed a hybrid PI-fuzzy logic controller based DC-DC converter. He analyzed one of the main limitations of the DC-DC converter which is an unregulated supply of voltage and current. A feedback controller for DC-DC boost converter is designed to obtain a constant output voltage. The converter is modelled and simulated by using MATLAB. The proposed system uses Fuzzy Logic Controllers (FLC) and FLC tuned by PI controller. The FLC gives an algorithm which can convert the linguistic control strategy based on expert knowledge into an automatic control strategy. In the fuzzy controller, fuzzy logic summarizes 25 rules of proposed control algorithm for getting a better output of FLC controller. The system result shows that FLC tuned by PI Controller is superior to the other control strategies because of fast transient response, minimum steady state error and good disturbance rejection under various variations of the operating conditions. Hence, it achieves the closest output voltage regulation. The converter proposed by the writer improves the response and minimizes the error signal and so provides desired response to optimize the output of controller of Sugeno based fuzzy logic controller the converter may be used in Type-2 Fuzzy Logic Controller on DC-DC Boost Converter.

Man Mohan Garg et al. [2015] analyzed DC-DC Zeta converter, which is a buck-boost type of converter and says the said converter yields DC output voltage with the same polarity that of the input voltage. The author discusses the design system of PI controller for a DC-DC Zeta Converter for Specific Phase Margin and Crossover Frequency. In this system, the duty cycle of the output voltage and small-signal transfer function of DC-DC Zeta converter are obtained using state-space technique and Leverrier algorithm. The PI controller is used for stability equations to meet specific phase margin and desired cross-over frequency. For designing PI controller, the system considers a Single Input Single Output (SISO) control system with plant transfer function and PI controller. The parameters of this PI controller are tuned to achieve specific phase margin of 55° at desired cross-over frequency.
12 KHz. The system result indicates the time responses and frequency responses of closed loop Zeta-converter show that the performance of compensated system is improved significantly.

Genc. N.et al. [2016] discussed controlling a DC-DC boost converter by using an Average Sliding Controller (ASC) cascaded with PI voltage controller. The proposed system’s topology is modelled and simulated by using MATLAB/Simulink. The system functioned under variable load. The output value of PI voltage controller is used as a current reference value for ASC which is used for current controller under variable load. ASC has a simple mathematical model, so it is an easy method for applications. The systems controlling AS controller have stability under variable condition. The input voltage of the system topology is multiplied with the output of the PI controller for input feed forward. The system has been analyzed with 50% load change to observe the dynamic behaviour of the output voltage. First, the topology is controlled by PI controller which has zero steady-state error. The system result indicates that the response of controller is improved in a sensitive implementation by using ASC. Then the simulation results of the PI-ASC controller are compared with those of PI-PI controller. The output voltage ripple of PI-ASC controller is less than the output voltage ripple of the PI-PI controller. Also, the settling time of the output voltage is least under PI-ASC controller.

Nibedita Swain et al. [2016] developed power converters which are very important in small power electronic devices due to their small size, light weight, high efficiency and high power density. He also discussed a comparative performance of DC-DC CUK converter using different controller techniques such as PI controller and fuzzy logic controller. The system design and simulation has been carried out using MATLAB/Simulink. The state-space averaging technique is used to convert a nonlinear model to a linear model. The PI controller is based on root locus method, and the designing of
the fuzzy logic controller is based on general knowledge of the dc-dc converter. Fuzzy Logic Controller (FLC) is cheaper to develop a wider range of operating conditions, and they are adjustable concerning natural language. In the fuzzy controller, fuzzy logic summarizes 49 rules of proposed control algorithm for getting the better output of FLC controller. The system result shows that the settling time and peak overshoot is reduced more using a fuzzy logic controller rather than using the PI controller. The values of time domain specifications have improved more in the fuzzy logic controller rather in PI controller.

Prabhu Omer et al. [2016] designed a Robust PID Controller for Buck Converter using Bat Algorithm because its PI controller’s response is sluggish and exhibits large deviations. With the introduction of the PID controller, the DC-DC converter that exhibits nonlinear behaviour due to switching changes over to linear behaviour. The system design and simulation were carried out using MATLAB/Simulink. In the proposed system, robust PID controller was designed for a voltage mode controlled buck converter with both variable input voltage and resistive load variation. The system was analyzed under two conditions, one with the variable input voltage and another with variable resistive load. The system result indicates the rise time, settling time and overshoot of the converter have been greatly minimized, thus leading to a faster dynamic response of the controller. Due to lower current and voltage ripples, the proposed system controller is well suited for applications requiring very less ripple content in their supply systems.

Yasser Moursy et al. [2016] discussed a fully-integrated solution for PI compensation circuits in current-mode DC-DC converters used in automotive applications. In automotive applications, the switching frequencies are low, and the conventional PI compensation circuits employ large capacitors for increasing the switching frequencies. The system simulations are simulated by using MATLAB/Simulink. In this system, the
mixed signal PI comprises an analog proportional amplifier and a digital integrator. The analog proportional amplifier provides the required response time and maintains system stability. The digital integrator block is used to eliminate the output voltage steady state error. This result highlights the capacity for integration of the proposed control loop along with its potential.

Zongxiang Chen et al. [2016] developed a Parallel DC-DC converter which can achieve both large capacity power supply and redundant fault tolerance. The author discusses PI Sliding Mode Controller for Paralleled DC-DC Converter. The proposed system has a combination of the proportional integral Sliding Mode (SM) control with the Master-Slave current sharing technology to achieve both current sharing and a better robustness in a parallel dc-dc converter. The small signal method is used to analyze the stability condition of the closed loop control system. The Field Programmable Gate Array (FPGA) was constructed for a parallel buck converter. The system has been designed on variable loads. The proposed system results are compared with the traditional double closed loop PI control. The system result shows a good dynamic performance even under variable load, and disturbance conditions have a good performance of load current sharing, high robustness, and reliability. The Sliding Mode (SM) control algorithm is suitable for the PWM parallel DC-DC converter system.

2.4 Modern Controllers for DC-DC converter

Kheirmand. M. et al. [2008] designed a DC-DC converter system, controlled under two different methods. In the first method, Pole Placement controller is used to optimize the DC-DC converter performance. In the second, Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) are used to obtain the best coefficients in them. The pole placement method is still fairly sufficient for most small control systems, and it gives the best introduction to the design of complex systems. The optimum design method for Pole Placement controller is able to control the dynamic behaviour of the
converter. The use of the genetic algorithm and Particle Swarm Optimization for the calculation of optimum coefficients of the gains in the design of Pole Placement controllers can bring about an optimum dynamic response. The system result shows Pole Placement controller methods are more satisfactory with Particle Swarm Optimization than the results of genetic algorithm method.

Yousefi. M. R. et al. [2008] developed a DC-DC converter to stabilize or control the DC voltage of a battery. The proposed system uses new several fuzzy logic controls law algorithms and PID controllers based on Genetic Algorithm (GA) and Particle Swarm Optimization (PSO), and these controllers are designed to eliminate the overshoot and reduce the settling time response. The system simulations are done using MATLAB software. In the fuzzy controller, fuzzy logic summarizes the fuzzy rules of proposed control algorithm for getting the better output of FLC controller. The system result shows that the PID control method is useful in controlling the output voltage of the step-down converter, and in optimizing the PID parameters through two optimizing methods (GA and PSO). It demonstrates the effectiveness of the PID controller with PSO applied to the state-space averaging DC-DC converter.

Sivakumar. A. et al. [2014] developed an intelligent fuzzy controller for positive output Relift LUO converter, which is a novel DC to DC voltage gain converter. The system uses voltage lift technique for the conversion of positive input source voltage to positive output load voltage. The fuzzy controller is implemented for the present Luo converter work. The fuzzy control is proposed as a computational intelligence technique for the purpose better regulation as well as the performance of the converter. The MATLAB/Simulation is used to obtain the system simulations. In the fuzzy controller, fuzzy logic summarizes 25 rules of proposed control algorithm for getting the better output of FLC controller. The proposed system was
developed in hardware by using TMS320F2407A processor. The system simulation results show that the proposed fuzzy controller regulates the output voltage of Positive Output Relift Luo converter of line and load disturbances satisfactorily.

Vinod.S.et al. [2015] developed a Robust Control of Parallel Buck Fed Buck Converter Using Hybrid Fuzzy PI Controller topology for high current application. In this system, an intelligent controller like the hybrid Fuzzy-PI controller is used and same system exhibits a good dynamic response. The controller responds quickest as fault-correction time intervals, which are decided based on the error between the desired and actual value. In the fuzzy controller, fuzzy logic summarizes 49 rules of proposed control algorithm for getting the better output of FLC controller. The parallel buck fed buck converter topology considered imposes less stress on the semiconducting device than the traditional method. The system results indicate the Hybrid Fuzzy PI controller is robust and reliable. The proposed system structure can also be extended with the self-tuned fuzzy controller which can provide better performance.

2.5 Summary

The survey clearly indicates that of the various voltage lift converters, Luo and super lift converters produce high gain with less complexity. The Luo converter with split capacitor produces enhanced performance compared to conventional Luo converter.