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Three-Phase High Frequency Isolated DC–DC Converter with PWM Generator

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Abstract: ***Basic power circuit of an isolated three -phase DC–DC converter consists of three stages: inverter stage in this stage the power switches (S1 to S6) practically realized by IGBT or MOSFET with body diode and parallel connected RC snubber circuits. Second one is high frequency isolated transformer. this transformer have three units of single phase high frequency transformer with star-connected primary and mesh connected secondary and thread output rectifier stage. Keeping in view of low voltage high current applications, different types of rectifiers such as forward type, center-tap, bridge, current doublers and Tripler are considered. On the basis of secondary side load sharing, transformer design and thermal heat dissipation, Three-phase, full diode bridge with three inductors are selected for low voltage high power and frequency. To control the output voltage against input source voltage and load variations, width of gate signals of power switches of three phase full bridge inverter are varied by the PWM control method. On the bases of duty cycle of switches, two control methods namely symmetric and asymmetric control are proposed The duty ratio of the upper group power switches (S1, S3, S5) in inverter legs is same as that of lower group of power switches(S2, S4, S6) in symmetrical control on the other hand in asymmetrical control duty ratio differs. To understand the steady-state analysis of proposed converter, power switching devices and passive components are considered to be lossless. The output voltage ripple is small and neglected and output inductors are large enough to ensure continuous of operation and ripple-free current. Switches of each inverter-leg are symmetrically and asymmetrically controlled and 120 degree phase shifted between each inverter-leg. To regulate the output voltage against line and load variation, duty cycle of power switch vs. of three phases, full bridge inverter is varied. Furthermore, duty cycle of switches also depends on the turn's ratio of transformer.***

Keywords: DC Supply, Three Phase Inverter, LC Filter, Isolated Transformer, DC Converter

1. Introduction

1.1 Overview

There are many application were high power and low voltage supply are use like as power supply for microprocessor, telecommunication equipments, chemical electrolysis, Aluminum, plotline, DC Arc furnace, Graphitizing Furnace, Copper refining, Plasma Torch, starting process of Aircraft, Large Hadrons Collider (LHC) and nuclear fusion research of magnetic confinement approach. For high power and low voltage the level of current are controls for controlling the level of current semiconductor family best suitable like as SCR, DIODE, IGBT, MOSFET, GTO, FCT etc In these all semiconductor IGBT and MOSFET are capable for withstand in the range of high power and low voltage supply by the use of IGBT semiconductor build a rectifier this rectifier know the high power rectifier this is also known as DC-DC converter mostly the high power rectifier suffer from severe current and voltage stresses to overcome these stresses use line frequency isolation based rectifier because of low cost, simple and well-established technique. Invariably, these rectifiers consist of power conditioning system

Keeping limitations of line frequency isolation based power converters in mind then high frequency isolation based power supply is suggested DC-DC converter are many type like as forward, fly-back, push-pull, half and full bridge etc but all these have more switching device and modules in rectifier circuit and its complexity increases when its use three of more phase in this thesis given their alternative form as three phase full bridge inverter feeding to isolated transformer. They have various advantages of the three-phase-isolated converters such as reduced size and weight of reactive components, high power application, lower rms current through the switches, etc The objective of this thesis is to evaluate the performances of high frequency isolated three-phase full bridge converter under symmetric and asymmetric control techniques and further, to investigate its suitability for applications require high power at relatively low voltage and high current

Basic power circuit of an isolated three -phase DC–DC converter consists of three stages: inverter stage in this stage the power switches (S1 to S6) practically realized by IGBT or MOSFET with body diode and parallel connected RC snubber circuits. Second one is high frequency isolated transformer. this transformer have three units of single phase high frequency transformer with star-connected primary and mesh connected secondary and thread output rectifier stage.

Keeping in view of low voltage high current applications, different types of rectifiers such as forward type, center-tap, bridge, current doublers and Tripler are considered. On the basis of secondary side load sharing, transformer design and thermal heat dissipation, Three-phase, full diode bridge with three inductors are selected for low voltage high power and frequency. To control the output voltage against input source voltage and load variations, width of gate signals of power switches of three phase full bridge inverter are varied by the PWM control method.

On the bases of duty cycle of switches, two control methods namely symmetric and asymmetric control are proposed The duty ratio of the upper group power switches (S1, S3, S5) in inverter legs is same as that of lower group of power switches(S2, S4, S6) in symmetrical control on the other hand in asymmetrical control duty ratio differs. To understand the steady-state analysis of proposed converter, power switching devices and passive components are considered to be lossless. The output voltage ripple is small and neglected and output inductors are large enough to ensure continuous of operation and ripple-free current. Switches of each inverter-leg are symmetrically and asymmetrically controlled and 120 degree phase shifted between each inverter-leg. To regulate the output voltage against line and load variation, duty cycle of power switch vs. of three phases, full bridge inverter is varied. Furthermore, duty cycle of switches also depends on the turn's ratio of transformer.

The proposed DC–DC converter is also operated under symmetrical and asymmetrical control in Symmetrical control method, whole operating region can be classified in four regions depending upon variation of duty cycle: Reg1 to Reg4. In this operation any instant only one power switch of Inverter Bridge conducts which makes incomplete circuit. When duty cycle exceed beyond, D > 0.5 i.e. Reg4, short circuit conditions occurs which leads to direct short circuit of dc source. Therefore the proposed converter under symmetric control operates mainly in two operating regions: Reg2 and Reg3 the sequence of conduction of power switches varies from region to region

During asymmetrical control method, duty cycle allows to vary between 0 and 1. Three operating regions as Reg1, Reg2 and Reg3 are identified. In each region, different group of power switches conduct. The control signals for power switches of bridge inverter under both control methods are given and depending on conduction of switches, various

Operating modes are identified. The LC filter is also designed in such way so that all the units are identical and the output voltage ripple is small.

There is a rising demand for power converters with variable size, low losses of power, high conversion efficiency and higher power density. Also, in many applications, there is a need for dc-to-dc converters to accept dc input voltage and provide regulated and isolated dc output voltage at a required voltage level including telecommunications equipment, process control systems, and in industry applications. This work presents the analysis, design, simulation results of three-phase high-frequency transformer isolated converters. The first converter presented is a three-phase LCC-type dc-dc converter with capacitor output filter including the effect of the magnetizing inductance of the three-phase HF transformer. The equivalent ac load resistance is derived and the converter is analyzed by using approximation analysis approach. Base on this analysis, design curves have been obtained Simulation results for the designed converters are given for input voltage and load conditions.

1.2 Literature Review

For medium to high power levels, single-phase dc-to-dc converters face severe component stresses. An alternative is the three-phase dc-to-dc converters with three-phase HF transformer isolation. Three-phase dc-dc converters with three-phase HF transformer isolation have many advantages over the single-phase dc-dc converters. Some of these advantages are: medium to high power application, low component stresses, small size filter elements, and HF transformer requires less magnetic core material and less weight. The increasing diversity of applications such as industrial, telecommunications, transports, aerospace, military, and the continuous demand for smaller, lighter, and more efficient high power supplies have forced to draw attention towards high frequency isolated, three-phase DC–DC converter. The proposed–DC converter can be used in applications which require very low voltage conversion ratio, isolation, good regulation against load and line disturbances, and fast dynamic response. In this thesis review of modeling, control and design of high-frequency isolated three-phase DC–DC converter. A brief literature on different types of three-phase dc-dc converter isolation transformer are as follows.

Rakesh Maurya , S.P. Srivastava, Pramod Agarwal investigated that the increasing diversity of applications such as industrial, telecommunications, transports, aerospace, military, and the continuous demand for smaller, lighter, and more efficient high power supplies have forced to draw attention towards high frequency isolated, three-phase DC–DC converter. The proposed–DC converter can be used in applications which require very low voltage conversion ratio, isolation, good regulation against load and line disturbances, and fast dynamic response. In this paper modeling, control and design of high-frequency isolated three-phase DC–DC converter is carried out under symmetrical and asymmetrical control with fixed frequency operation and its steady state analysis is presented according to the description of the operation stages of the converter. A 750 W, 5 V/150 A prototype model of proposed DC–DC converter is built and tested at different operating conditions. Based on experimental results under both control methods, performances of proposed converter have been investigated in view of low voltage high current applications [1].

According to Akshay K. Rathore an interleaved soft-switched active-clamped L–L type current-fed half-bridge isolated dc–dc converter has been proposed. The L–L type active-clamped current-fed converter is able to maintain zero-voltage switching (ZVS) of all switches for the complete operating range of wide fuel cell stack voltage variation at full load down to light load conditions. Active-clamped circuit absorbs the turn-off voltage spike across the switches. Half-bridge topology maintains higher efficiency due to lower conduction losses. Soft switching permits higher switching frequency operation, reducing the size, weight and cost of the magnetic components. Interleaving of the two isolated converters is done using parallel input series output approach and phase-shifted modulation is adopted. It reduces the input current ripple at the fuel cell input, which is required in a fuel cell system and also reduces the output voltage ripples. In addition, the size of the magnetic/passive components, current rating of the switches and voltage ratings of the rectifier diodes are reduced [2].

Abdul Hamid Bhat, Pramod Agarwal evaluated that in addition to other sources of harmonics and reactive power. The design, development and successful application of single-phase, power quality improvement converters in domestic, commercial and industrial environment has made possible the design and development of three-phase, power quality improvement converters and their widespread use in different applications. This paper deals with a comprehensive review of three-phase, power quality improvement converter configurations, control approaches, performance on supply and load sides in terms of input power factor, THD and well-regulated, reduced-rippled dc output, power rating, cost and selection for specific applications. It also provides state-of-the-art of power quality improvement converter technology to researchers, designers and engineers working on three-phase, switched-mode ac–dc converters.

Dan Kinzer describes recent advances in power semiconductor devices, integrated circuits, and packages for DC/DC converter applications. Special emphasis is placed on the latest discrete power MOSFET devices and packages. Features and trends in ICs for control of synchronous buck converters are highlighted as well. The paper will also cover a new class of miniaturized hybrid assembly that sets new efficiency standards for high current low output voltage applications.

Laureano Piris-Botalla, Germán G. Oggier, Andrés M. Airabella, Guillermo O. García Analyzed the Power losses of a bidirectional three-port DC–DC converter to be used in hybrid electric systems as a function of the voltage conversion ratios and the output power are evaluated in this work. An analysis and characterization of the current on the switches into the whole converter operating range are presented. This analysis allows finding the semi conductor conduction intervals, necessary to calculate the power losses. Such losses are evaluated considering both switching and conduction semiconductor losses as well as those in the transformer. The variables used in this evaluation are voltage conversion ratios and transformer parameters like leakage inductances and turns ratios. Design considerations for the high frequency transformer that allow minimizing the total power losses are proposed. Simulation results are presented in order to validate the theoretical analysis. [5]

C.A. Ramos-Pajaa, E. Arangoa, R. Giral b, A.J. Saavedra-Montesa, C. Carrejoc analyzed the cascade connection of a low-ripple voltage doublers pre-regulator and a classical boost converter regulator is proposed to improve the efficiency of the full system due to the reduction in average currents of all boost converters and the smaller duty cycle required for the conventional boost regulator. The pre-regulator inherent low input current ripple, which operates at a 50% duty cycle in complementary interleaving mode, makes the system suitable for current ripple sensitive power generators such as fuel cells or photovoltaic modules. In addition, the proposed solution increases the maximum voltage conversion ratio achievable, and the independent control schemes of the pre-regulator and the boost stage do not increase the control complexity of the system.[6]

Vahid Dargahi a, Arash Khoshkbar Sadigh b, Mohammad Reza Alizadeh Pahlavani c, Abbas Shoulaie proposed the Multilevel power converters are key elements in the electrical grid-tied energy systems. Vahid Dargahi presents a novel topology for stacked multi cell (SM) multilevel converters. The suggested SM converter has considerable interests of applications for interconnection of energy systems (renewable energy generation systems, energy storage systems, HVDC (high voltage direct current) systems, FACTS (flexible alternating current transmission system) devices, and custom power devices) to the electric power systems. The main advantages of the proposed converter, compared to the conventional SM converter, for attaining the aforementioned purpose are the reduction of the DC voltage energy sources from two to one, power switches (IGBT's) voltage rating, converter cost and size, losses, and installation area. The proposed SM converter has been analytically modeled by obtaining the switching instants of the PWM in terms of the Kapteyn series. Numerical solution results for the derived model of the proposed converter, simulation results, and measurements taken from an experimental set-up are presented in order to validate the operation and performance of the suggested multilevel topology. The proposed SM converter has been exploited in a dynamic voltage restorer (DVR). This proposed custom power device is based on the one energy storage device (battery, capacitor, super capacitor) with halved voltage rating owing to utilizing the suggested SM multilevel inverter (DC/AC converter) as an interface between its energy storage component and the electrical grid. Simulation results confirm the capability of the suggested energy storage based grid-tied custom power device (DVR) in solving power quality problems. [7]

Bulent Vural Given the concept that the environmental issues have become more serious recently, interest in renewable energy systems, such as, fuel-cells (FCs) has increased steadfastly. Among many types of FCs, proton exchange membrane FC (PEMFC) is one of the most promising power sources due to its advantages, such as, low operation temperature, high power density and low emission. However, using sole PEMFC for dynamic loads may not be feasible to satisfy the peak demand changes. Therefore, hybridizing PEMFC and an energy storage system (ESS) decreases the FC cost and improves its performance and life. Ultra capacitor (UC) is the most powerful candidate to hybridize with PEMFC for dynamic loads. The DC-DC converter is the key enabling technology for hybridization of PEMFC and UC. Generally, the efficiency and performance of hybridization is largely limited by the converter topology employed for the mentioned hybridization. Integrating each source (PEMFC and UC) with a DC-DC converter is not feasible in terms of cost, performance, and control. Due to the above mentioned reasons, an attractive converter topology which can combine PEMFC and UC is strongly required. In this regard, the objective of this study is to design and simulate a novel double input DC-DC converter based on current addictively [8]

Tohid Nouri, Ebrahim Babaei, Seyed Hossein analysis that an isolated DC–DC converter with high voltage gain and low voltage stress on switches is proposed in this paper. For absorption of energy, n stages of diode–capacitor–inductor (D–C–L) units are used at the input that results in higher voltage gains. Actually, the proposed converter generalizes the voltage lift circuit and combines it with a voltage multiplier cell. Therefore comparing to structures with one stage of D–C–L unit, it will be feasible to achieve supposed voltage gain at lower duty cycles. Lower values of duty cycle will result in increasing of converter controllability and increasing of operation region. This paper focuses on the generalized steady state analysis of the proposed converter for three regions of operation named as continuous conduction mode (CCM), boundary conduction mode (BCM) and discontinuous conduction mode (DCM). Theoretical analysis and performance of the proposed converter will be verified by both simulation and experimental results. [9]

Yong Wanga, Seeyoung Choi b, Eunchul Lee c given that Proton exchange membrane fuel cell (PEMFC) systems for residential application require efficient and ripple-mitigating power conditioning system (PCS). The key point to reach it, is the design and control of the dc–dc converter. Based on the theoretical and experimental analysis of the traditional converter, this paper proposes a novel parallel-series full bridge (P-SFB) dc–dc converter, and improves its phase shifting scheme. This paper also proposes a novel controller for low frequency ripple current suppressing applied on the converter. The experimental results verify that, the dc–dc converter achieves a peak efficiency of 95.5%. Therefore PCS's maximum efficiency reaches 92.9%. And the input current ripple is reduced significantly with the new controller. [10]

Zhang Xuan1,Huang Shenghua1,Ning Guoyun2 discusses the detailed operations of a three-phase dual active bridge bidirectional zero-voltage switching(ZVS) DC/DC converter (TPDAB) which transfers a bidirectional power flow between a 12V net and a high voltage DC net. The converter is controlled by phase-shift-modulation (PSM) with a fixed duty cycle D=1/3. It features isolation, smoother drawing and injecting current from the 12V net, smaller capacitances; smaller switch current stress, ZVS over a wide range, high efficiency and a large power handling capability. The mathematic model is analyzed. The soft-switching principle is described and its ZVS criteria's are derived. The simulation and experimental results are provided to verify the theoretical analysis.[11]

Siebert Anthony, Troedson, Anders, Ebner Stephan. compares the present available converter technologies and provides an assessment of the advantages *I* disadvantages offered by each technology. The latest advances in high power semiconductor devices have resulted in the introduction of new concepts for high power rectifier systems. A comparison of traditional technologies and future technologies is made. The increased use of modem IT technology will also be briefly reviewed. [12]

Ruan Xinbo, Wu Chen, Lulu Cheng, Tse CK, Hong Yan, Zhang Tao. Given the concept of input-series–output-parallel (ISOP) converter, which consists of multiple dc–dc converter modules connected in series at the input and in parallel at the output, is an attractive solution for high input voltage and high power applications. This paper reveals the relationship between input voltage sharing (IVS) and output current sharing of the constituent modules of the ISOP converter. A novel IVS control strategy, which is decoupled with the output voltage regulation, is proposed. This control allows IVS and output voltage regulation to be designed independently. An ISOP converter, which uses the phase-shifted full-bridge (PS-FB) converter as the basic module, is considered. Based on the proposed control strategy, this ISOP converter together with the control circuit can be decoupled from several independent single input and single-output systems. An ISOP converter consisting of three PS-FB modules is used to illustrate the design procedure, and a 3-kW experimental prototype is fabricated and tested. [13]

Huang Yuehui, Tse Chi K, Ruan Xinbo. Discusses the general control problems of dc/dc converters connected in series at the input. As the input voltage is shared by a number of dc/dc converters, the resulting converter relieves the voltage stresses of individual devices and hence is suitable for high input-voltage applications. At the output side, parallel connection provides current sharing and is suitable for high output-current applications. Moreover, series connection at the output side is also possible, resulting in output voltage sharing. Theoretically, from a power balance consideration, one can show that fulfillment of input-voltage sharing implies fulfillment of output-current or of output-voltage sharing, and vice versa. However, the presence of right-half-plane poles can cause instability when the sharing is implemented at the output side. As a consequence, control should be directed to input-voltage sharing in order to ensure a stable sharing of the input voltage and of the output current (parallel connection at output) or output voltage (series connection at output). In this paper, general problems in input-series connected converter systems are addressed. Minimal control structures are then derived and some practical design considerations are discussed in detail. Illustrative examples are given for addressing these general control considerations. [14]

Rodríguez José R, Dixon Juan W, Espinoza José R, Pontt Jorge, Lezana Pablo given the idea of new regulations impose more stringent limits on current harmonics injected by power converters that are achieved with pulse width-modulated (PWM) rectifiers. In addition, several applications demand the capability of power regeneration to the power supply. The paper presents the state of the art in the field of regenerative rectifiers with reduced input harmonics and improved power factor. Regenerative rectifiers are able to deliver energy back from the dc side to the ac power supply. Topologies for single- and three-phase power supplies are considered with their corresponding control strategies. Special attention is given to the application of voltage- and current- source PWM rectifiers in different processes with a power range from a few kilowatts up to several megawatts. paper also shows that PWM regenerative rectifiers are a highly developed and mature technology with a wide industrial acceptance. [15]

Ayyanar R, Giri R, Mohan N explores a new configuration for modular dc–dc converters, namely, series connection at the input, and parallel connection at the output, such that the converters share the input voltage and load current equally. This is an important step toward realizing a truly modular power system architecture, where low-power, low voltage, building block modules can be connected in any series/parallel combination at input or at output, to realize any given system specifications. A three-loop control scheme, consisting of a common output voltage loop, individual inner current loops, and individual input voltage loops, is proposed to achieve input voltage and load current sharing. The output voltage loop provides the basic reference for inner current loops, which is modified by the respective input voltage loops. The average of converter input voltages, which is dynamically varying, is chosen as the reference for input voltage loops. This choice of reference eliminates interaction among different control loops. The input-series and output-parallel (ISOP) configuration is analyzed using the incremental negative resistance model of dc–dc converters. Based on the analysis, design methods for input voltage controller are developed. Analysis and proposed design methods are verified through simulation, and experimentally, on an ISOP system consisting of two forward converters.[16]

Wallace Ian, Bendre Ashish, Nord Jonathan P, Venkataramanan Giri. Given the A new thyristor current-source rectifier that achieves unity power factor, low-current total harmonic distortion (THD), and dc-bus current and voltage control is presented. The rectifier is suitable for high-power applications such as induction heating and dc arc furnaces. It combines a traditional six-pulse thyristor bridge and a dc chopper that together solve power quality problems such as poor power factor and flicker generation. This topology achieves low input current THD and dc power control without additional power-factor-correction equipment, harmonic trap filters, use of multiple pulse rectifiers, or high- -factor transformers.[17]

Xu Peng, Yuan-Chen Ren, Ye Mao, Lee FC.Proposes an innovative interleaving concept for low-voltage high-current dc/dc converters. Instead of using paralleled MOSFETs running at higher frequency, the parallel-secondary sides are interleaved while the primary side remains same. By using this concept, a family of novel interleaved dc-dc converters are proposed for VRh4 applications. The proposed interleaved converters use the same amount of silicon as conventional non-interleaved ones. Because of the reduced switching frequency for the synchronous MOSFET, the body diode conduction losses and reverse recovery related losses are reduced significantly. The interleaving effect results in the reduced filter size and improved transient response. The proposed concept was demonstrated on a push-pull forward VRM, which delivers power from a 48-V input to a 1.2-1.5 VI70 A microprocessor load. The proposed concept is generalized to more than two interleaved secondary sides, and the extensions to soft switching topologies are also given.[18]

Prasad AR, Phoivos D, Ziogas Stefanos Manias proposes the use of three-phase inverter circuits in **SMR** converters. The resulting advantages include the following: 1) **A** dramatic increase (by a factor of three) of input current and output voltage chopping frequencies **2)** lower rms current through the inverter switches or higher power transfer for the same switch current and voltage stresses 3) reduction in size of reactive (filter) components **4)** better transformer copper and core utilization *5)* inherent delays in switching actions (such as storage time in BJT's) do not pose conduction overlap problems under converter overload conditions. The last advantage is particularly important when designing the converter for large input voltage fluctuations. However, the proposed topology also exhibits the disadvantages of requiring higher total switch volt-ampere rating and increased power and control circuit complexity. [19]

1.3 Objective of This Thesis

This work presents the analysis, design, simulation results of three-phase high-frequency transformer isolated converters. The first inverter presented is a coveted DC to three phases AC with capacitor output filter including effect of the magnetizing inductance of the three-phase high frequency isolated transformer. Base on analysis, design curves have been obtained. Simulation results for the designed converter are given for input voltage and load conditions. It is shown that the converter works in zero-voltage switching at input voltage and load. A three-phase (LC) L-type dc-dc converter with capacitive output filter has been proposed. Operation of the converter has been presented using the operating waveforms and block diagram during different intervals. An approximate analysis approach is used to analyze the converter operation, and design procedure is presented. Simulation results for the designed converter are given for input voltage and load. Major advantages of this converter are the leakage and magnetizing inductances of the high-frequency transformer are used and the output rectifier voltage is clamped to the output voltage. The converter operates in PWM -switching for the inverter switches for supply voltage with symmetrical and asymmetrical analysis approach and load. A three-phase high-frequency transformer isolated L-type dc-dc converter with inductive output filter using fixed frequency control is proposed. The converter operation for different modes is presented using the operating waveforms and equivalent circuit diagrams during different intervals. Based on the analysis, design curves were obtained and the design procedure is presented. The designed converter is simulated using MATLAB software to predict the performance of the converter for variations in supply voltage and load conditions. The converter operates in PWM for the inverter switches with minimum input voltage and loses PWM for three switches in each bridge for higher input voltages. Larger the value of capacitance lesser the voltage stress on the rectifier side and induces high ripple current. In the present work, an attempt is made to introduce a number of numerical -and analytical methods supported by practical and mathematical processes. The aim is to examine the main factors that affect the performance of high frequency transformers used in power supply units. These factors are, winding losses, leakage, winding capacitances, core loss etc. A block diagram shown in fig 1.1 for describe the objective of this works

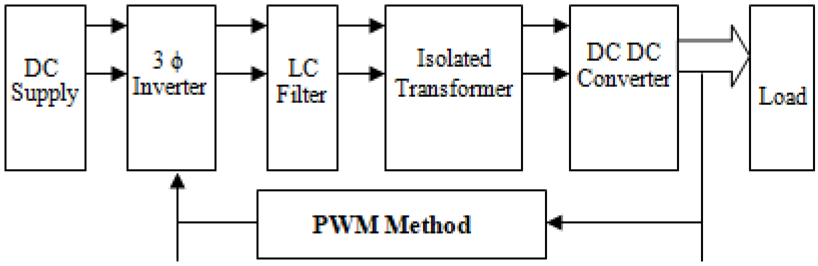


Figure 1.1: Block diagram for understands the objective of thesis

1.4 Organization of the Thesis

The technique presented in the literature allows an three level inverter, DC-DC bridge converter and isolated transformer control by PWM technique and flitted by LC filter converter have two mode of control symmetrical and asymmetrical experiment and different result are done using MATLAB/SIMULINK.

The work presented in this thesis is organized in five chapters.
Chapter 1 is entitled introduction of thesis and literature review.
Chapter 2 is entitled high frequency isolated transformer
Chapter 3 is entitled DC-DC converter, three level inverter, PWM technique and different type filter.
Chapter 4 is entitled MATLAB modeling and simulation results of proposed system**.**
Chapter 5 is entitled it describes the conclusion which is drawn from results & future scope of work has been presented

2. High Frequency Isolated Transformer

Application where an electronics device is use to supply or consumer electrical power for household and industries application and utility of supply line, regulatory agencies require electrical isolation for safety reasons. In this thesis electrical isolation is done by a high frequency transformer utilized within a DC-DC converter of a power conditioning system.

To understand how to electrical isolation is achieved with a line frequency transformer the block diagram shown in figure 2.1 a dc supply is converted into a ac supply by using three level inverter this three phase supply is isolated by isolated transformer the high frequency isolated use by DC-DC converter.

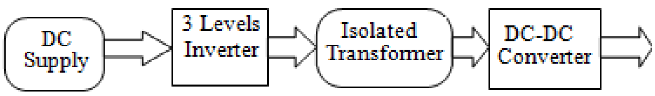


Figure 2.1: Blocks Diagram for Isolation of Supply

2.1 Three Phase Transformer

Transformer power levels range from low-power applications, i.e. consumer electronics power supplies to very high power applications, i.e. power distribution systems. For higher-power applications, three-phase transforms are generally used. The typical construction of a three-phase transformer is shown in Figure 2.2 the detailed analysis of this circuit is not straight forward since there are various combinations of flux paths linking different windings. For this reason, the three-phase transformer will be modeled as three independent single-phase transformers herein.

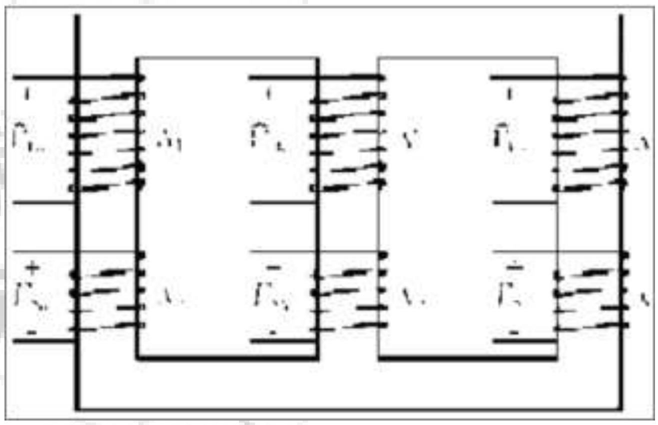


Figure 2.2: Three phase transformer winding

For practical calculations, it is easy to model the three-phase transformer as three ideal transformers as shown in Figure 2.3 Since these transformers are ideal, the secondary voltages are related to the primary voltages by the turn's ratio according to

$$V_{2a} = \frac{N2}{N1} V_{1a} \tag{1}$$

$$V_{2b} = \frac{N2}{N1} V_{1b} \tag{2}$$

$$V2c = \frac{N2}{N1} V_{1c} \tag{3}$$

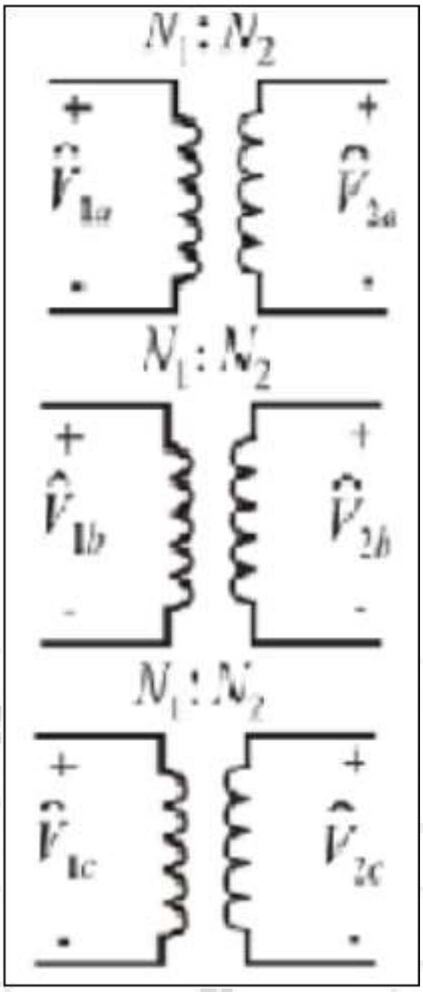


Figure 2.3: Three Idea Tansformer

Considering the individual transformers of Figure 2.3, and that both delta and Y connections are possible for the primary and secondary windings, there are four possible combinations of transformer connections. The easiest combinations are the Y-to-Y connection and the delta-to-delta connections shown in Figures 2.4 and 2.5 respectively. In these cases, the line-to-line voltages on the secondary side are directly proportional to voltage of the primary side through the turn's ratio. Therefore, the following relationship for both connections.

$$V_{ab} = \frac{N2}{N1} V_{AB} \quad (4)$$

In Figures 2.4 and 2.5, the ideal transforms are schematically rotated by 120^{o} from each other to represent a 120^{o} electrical displacement in the voltages. The voltage labels on the individual coils correspond to the labels in Figure 2.3. An equation similar to (4) can be derived to relate the primary and secondary currents if desired.

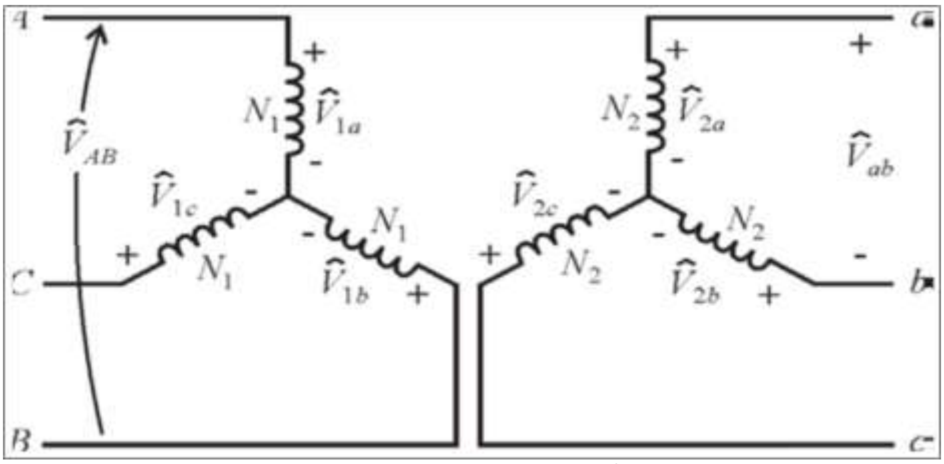


Figure 2.4: Y-to-Y three transformer rotted 120^{o} line to phase voltage

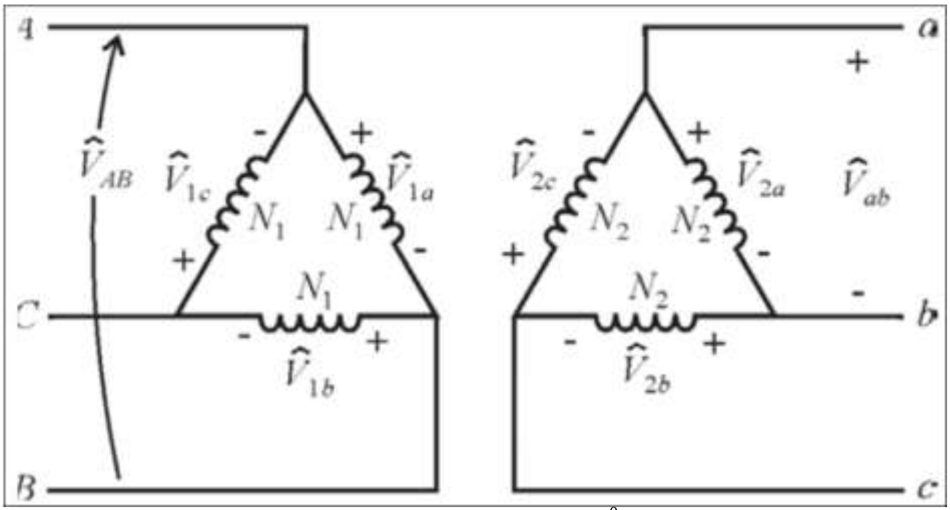


Figure 2.5: delta delta transformer display 120^0 line to phase voltage

The delta-to-Y connection is shown in Figure 2.6. From the ideal transformer equations, it can be determined that

$$V_{ab} = \frac{N2}{N1}(v_{1a}-V_{1b}) = \frac{N2}{N1}(V_{BC} - V_{AB}) \qquad (5)$$

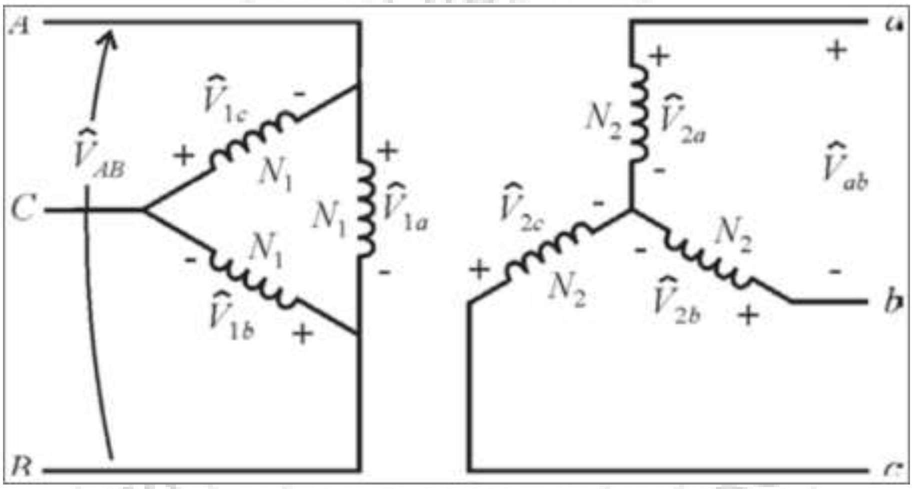


Figure 2.6: delta-to-Y connection three phase transformer

In this analysis A-B-C sequence is assumed. If a source does not have this sequence the input lines can be relabeled so that it does. With this sequence, (5) is equivalent to

$$Vab = \frac{N2}{N1}\sqrt{3}\, VAB < 30^0 \qquad (6)$$

As can be seen, the secondary line-to-line voltage leads the primary by 30^o. A factor of $\sqrt{3}$ is also inserted in the magnitude calculation as well.

The Y-to-delta connection is shown in Figure 2.7. With this arrangement, it can be shown that

$$Vab = \frac{N2}{N1}\frac{1}{\sqrt{3}}\, VAB < -30^0 \qquad (7)$$

In this case, the turn's ratio is divided by $\sqrt{3}$ and the secondary phase lags by 30^o.

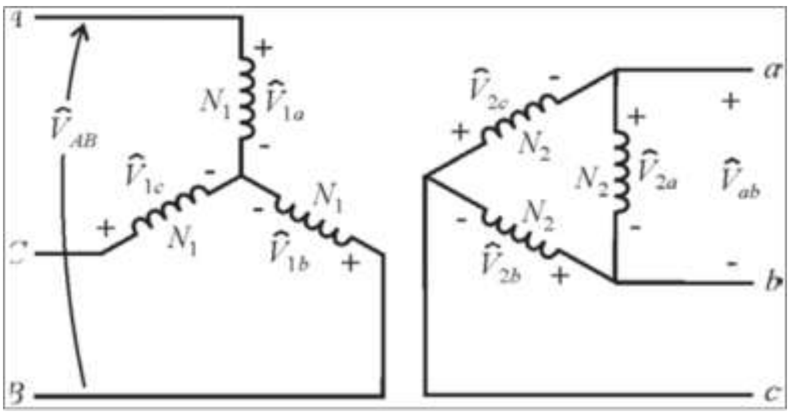


Figure 2.7: Y to delta connection

In initial power systems, two-phase transmission was used as well as three-phase. To supply a two-phase system from a three-phase source, two transformers were connected in the Scott-T connection shown in Figure 2.8. In this case, the primary windings must have tap locations at 1/2 and $\sqrt{3}$ /2. As it turns out, many 240-V laboratory transformers have tap settings at 120-V and at 208-V (which is nearly $\sqrt{3}$ /2). Considering the connection diagram of Figure 2.8 and the ideal transformer relationships,

$$V_a = \frac{N2}{N1}\frac{2}{\sqrt{3}}(V_{AB} + ½ V_{BC}) \quad (8)$$

$$V_b = \frac{N2}{N1} V_{BC} \quad (9)$$

In terms of the primary voltage V_{AB} the secondary voltages are

$$Va = \frac{N2}{N1} V_{AB} < -30^0 \quad (10)$$

$$Vb = \frac{N2}{N1} V_{AB} < -120^0 \quad (11)$$

As can be seen, there is a 90° phase relationship between the two secondary voltages which is necessary in a two-phase system.

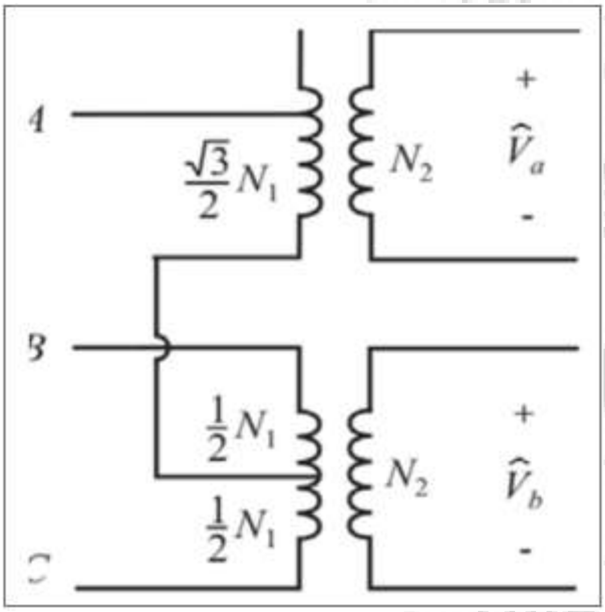
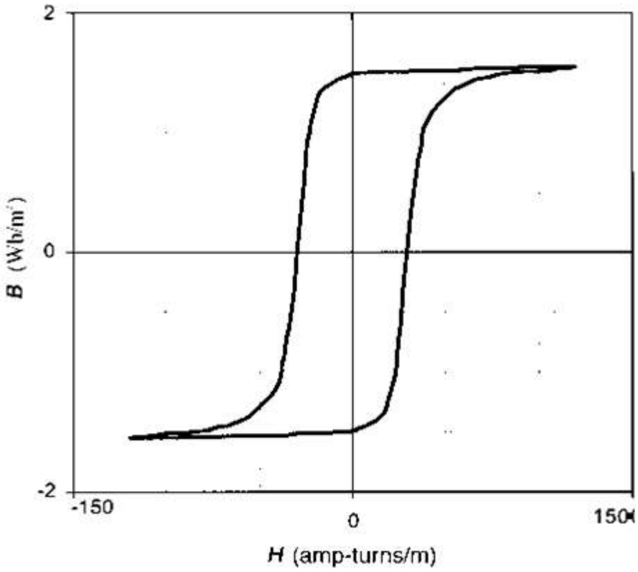


Figure 2.8: Scott-T connection

2.2 Transformer Design

2.2.1 Magnetic behavior

When a magnetic material is put into a magnetic field, H, the molecules in that material will start to align with it. During this magnetization process energy barriers have to be overcome. Therefore the magnetization will always lag behind the field. This process will create a Hysteresis loop as can be seen in Figure 2.9



A magnetic core with zero magnetism from start will start from **P1** in the figure where B=0 and H=0. When the magnetic core is put into a magnetic field, the magnetic field in the core, B, will rise. This rise is not linear and will flatten, if the core is fully utilized, until it reaches point **P2**, where an additional increase of the magnetic field will no longer have an effect on the core. In this point it is said that the core has reached saturation.

When the external field is then decreased, the field within the core will also decrease until it reaches point **P3**. The core is no longer subjected to an external field but there is still some amount of flux density in the core. This amount of flux density still present in the core is called residual magnetism and is referred to as permanence.

By reversing the external field, the field within the core will reach **P4**. This point of zero crossing is called the point of coercively.

All this above will repeat itself for the reversed external field, the field within the core will yet again reach the saturation in point **P5**.

2.2.2 Core Materials

2.2.2.1 Soft iron

Soft iron is used in electromagnets and in some electric motors. Iron is a common material in magnetic core design as it can withstand very high levels of magnetic field, up to several Tesla. In contrast to hard irons, soft iron does not remain magnetized when the field is removed which is sometimes important. But to use a bulk of soft iron is not possible since it will suffer from large eddy currents which will lead to undesirable heating of the iron. There are mainly two techniques to reduce these eddy currents. One way is to use laminated magnetic cores. This will increase the resistance and thereby decrease the eddy currents. The other way is to add silicon (3-5%), this will result in a drastic increase of the resistivity, up to four times higher.

2.2.2.2 Iron powder

Iron powder cores consists of small iron-parts that is electrical isolated from each other, this leads to a higher resistivity than in laminated cores and also thereby lower eddy currents. This material can also be used for much higher frequencies. Cores with this material are most commonly used in applications such as filter chokes in SMPS and as EMI-filters due to the low permeability. *Some alloy* is one type of product where iron powder has been compressed in a specific way to obtain beneficial properties. A unique 3D-shape of the particles will improve the performance.

2.2.2.3 METGLAS

Metglas is an amorphous metal, a metal that do not have a crystalline structure like other magnetic materials. Instead the atoms are randomly arranged, which will lead to up to 3 times higher resistivity than that for crystalline counterparts. For this material there also exist different kinds of alloys which will have different affects on the coactivity, permeability etc.

2.2.2.4 FERRITES

Ferrite is a class of ceramic material with useful electromagnetic properties. It is basically a mixture between iron oxide and different kinds of metal oxides. Addition of these kinds of metal oxide in various amounts allows the manufacturer to produce many types of ferrites for different applications. Ferrite cores have very high permeability. This allows low loss operation with really high frequencies. The resistivity is really high so eddy currents can be neglected when it comes to ferrite cores.

2.3 High Frequency Transformers

Two or more wire windings placed around a common magnetic core is the physical structure of a transformer. Its electrical purpose is to transfer power from the primary winding to the other windings with no energy storage or loss. For HW show the B-H curve for a transformer with transferred and core loss energy indicated. The choice of circuit topology obviously has great impact on the transformer design. Fly back transformer circuits are used primarily at power levels in the range of 0 to 150 Watts, Forward converters in the bridge usually over 500 Watts. The waveform and frequency of currents in transformers employed in these unique circuit topologies are all unique.

2.3.1 Geometry of Copper Windings and Core Wire Winding

Lets for simplicity consider only two wire windings wound upon one magnetic core, which acts to couple the magnetic flux between the two coils with near unity transfer. The main purpose of a power transformer in Switch Mode Power Supplies is to transfer power efficiently and instantaneously from an external electrical source to external loads placed on the output windings. In doing so, the transformer also provides important additional capabilities:

1) The primary to secondary turn's ratio can be established to efficiently accommodate widely different input/output voltage levels.
2) Multiple secondary's with different numbers of turns can be used to achieve multiple outputs at different voltage levels and different polarities.
3) Separate primary and secondary windings facilitate high voltage input/output isolation, especially important for safety.

For the case of multiple windings the competing issues are more complex as we will see at the end of this lecture. It will require Lagrangian optimum analysis using one variable for each wire coil. In the end the winding area allotted to each coil winding will vary as its power handling requirement compared to the total power level.

All the wire windings, wound on a given core must fit into its one wire winding window which we term either AW or WA in the text below. Both symbols are found in the transformer literature. Much of the actual winding area is taken up by voids between round wires, by wire insulation and any bobbin structure on which the wire turns are mounted as well as insulation between high voltage and low voltage windings. In practice, only about 50% of the window area can actually carry active conductor, this fraction is called the fill factor. In a two-winding transformer, this means that each winding can fill not more than 25% of the total wire winding window area.

To control the power level of AC and DC the power electronics device are use for their several advantage this chapter discuses the different type semiconductor devices which use this thesis

3. Diode

A diode is a semiconductor device that conducts electric current in only one direction.

When the diode is forward biased, it begins to conduct with only a small voltage over it. This forward voltage Vf is on the order of 1V and due to the steep characteristics, this voltage is almost constant independently of the current level. It should be said, that for power diodes the slope resistance is relatively large compared to small signal diodes.

When the diode is reversing biased, a small amount of leakage current will appear. This current is very small, a few µA or less so it is usually neglected.

However, all diodes have a maximum reverse voltage Vrated it can withstand. If this voltage exceeds the diode will fail and start to conduct a large current in reverse direction, this is called breakdown.

A diode turns on rapidly so during turn-on it can be considered as an ideal switch. This is not the case at turn-off since the diode current reverses for a reverse-recovery time trr before falling to zero. This reverse recovery current is necessary to remove excess carriers in the diode and it will introduce an energy loss Qrr at each turn-off.

Depending on the application requirements, there exist a range of different diodes

3.1.1 Shottky diodes

These diodes have a very low forward voltage drop (~0.3V) and are typically used in applications with very low output voltage.

3.1.2 Fast recovery diodes

These diodes are designed to have a very short reverse recovery time trr and are typically used in high-frequency applications

3.2 MOSFET

A metal oxide semiconductor field effect transistor, MOSFET, is a voltage controlled semiconductor device whose function is to control the flow of current. Depending on different doping-techniques, MOSFETs can be either N-channel or P-channel. The most popular type of MOSFET in switching circuits is the N-channel due to the low on-state resistance compared to a P-channel

The control signal in a MOSFET is the applied voltage between gate and source Vgs. If this voltage is greater than the threshold voltage Vgs(th) the semiconductor starts to conduct and the current level is related to the level of Vgs as can be seen in Figure 2.6. MOSFETs have a very high impedance gate which requires only a small amount of energy to switch the device.

There are some static and dynamic key parameters to consider when choosing MOSFET.

3.2.1 Static parameters

V (BR) DSS: This is the maximum voltage the switch can withstand without breakdown. This voltage should be greater than or equal to the rated voltage of the device.

Rds(on): This is the resistance in the switch during ON-state. It is temperature dependant and directly related to the conduction losses in the MOSFET. A low Rds(on) will give low conduction losses. The on-state resistance for MOSFETs is increasing rapidly with the blocking voltage rating V (BR) DSS so devices with low voltage ratings are the only option to get a low on-state resistance. This resistance varies from mohms to several ohms.

3.2.2 Dynamic parameters:

Qg,tot: This is the total gate charge. This charge can be represented by a capacitor between gate and source Qgs and a capacitor between gate and drain, Qgd (often called the Miller charge). This parameter is temperature dependant and directly related to the MOSFET speed, as the value of the capacitors determines the response time when the voltage Vgs is applied. A lower value of Qg,tot will then give faster switching speeds and consequently lower switching losses. MOSFET's are in general very fast, with switching times from tens of nanoseconds to a few hundred nanoseconds

Qrr, trr, Irr: The MOSFETs are also having an intrinsic diode from drain to source. The reverse recovery charge Qrr reverse recovery time trr and reverse recovery current Irr is parameters that are related to the body diode reverse recovery characteristics. It is important that the recovery time trr of the diode is faster than the rise/fall time so it doesn't affect the circuit. All of these parameters are temperature dependant and lower trr, Irr and Qrr improves THD, EMI and efficiency.

3.3 IGBT

An insulated gate bipolar transistor, IGBT, is a voltage controlled semiconductor device with the big difference from MOSFETs, that this is a minority carrier device. This will have a strong influence on the performance of the device. Regarding the physical setup of an IGBT, it can be divided into two categories: the non-punch through IGBT (NPT-IGBT) and the punch-through IGBT (PT-IGBT). The punch-through IGBT has an additional N+ buffer layer, which may further improve the performance of the IGBT

Similar to the MOSFETs, the IGBT has a very high impedance gate which requires a small amount of energy to switch the device. In contrast to MOSFETs, there exist IGBTs with large blocking voltage ratings that has small on state voltage

IGBTs suffer from phenomena called "tailing" The current tail will cause an additional energy loss to Eoff from t2 to t3. This extra energy loss will cause extra high turn-off losses for IGBTs. Because of this increase in switching losses, MOSFETs are preferred instead of IGBTs for really high frequency applications.

3.4 DC-DC Converter

A DC-to-DC converter is a device that has a DC input voltage and produces a DC output voltage. The output produced is at a different voltage level than the input. In addition, DC-to-DC converters are used to provide noise isolation, power bus regulation, etc. This is a summary of some of the popular DC-to-DC converter topologies:

3.4.1 Buck Converter Step-Down Converter

In this circuit the semiconducting device (transistor) turning ON will put voltage V_{in} on one end of the inductor. This voltage will tend to cause the inductor current to rise. When the transistor is OFF, the current will continue flowing through the inductor but now flowing through the diode. We initially assume that the current through the inductor does not reach zero, thus the voltage at Vx will now be only the voltage across the conducting diode during the full OFF time. The average voltage at V_x will depend on the average ON time of the transistor provided the inductor current is continuous.

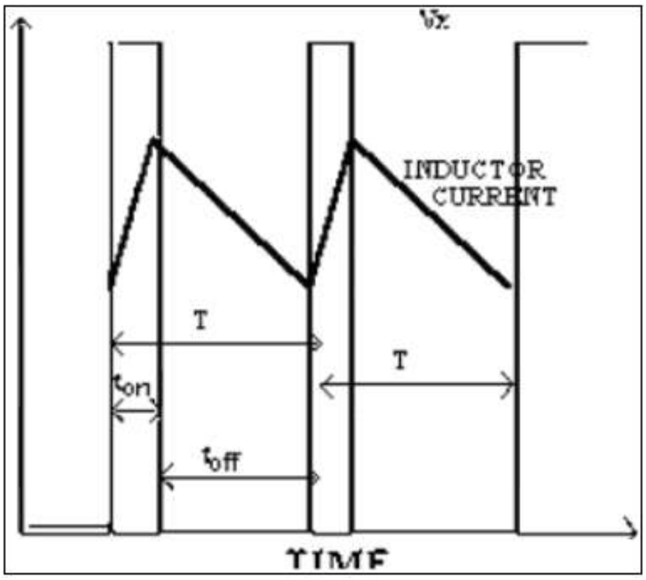


Figure 3.1: graph of PWM buck converter step-down converter

To analyses the voltages of this circuit let us consider the changes in the inductor current over one cycle. From the relation the change of current satisfies

$$\mathbf{di} = \int_{ON} (\boldsymbol{Vx} - \boldsymbol{V}0)\boldsymbol{dt} + \int_{OFF} (\boldsymbol{Vx} - \boldsymbol{V}0)\boldsymbol{dt} \quad (1)$$

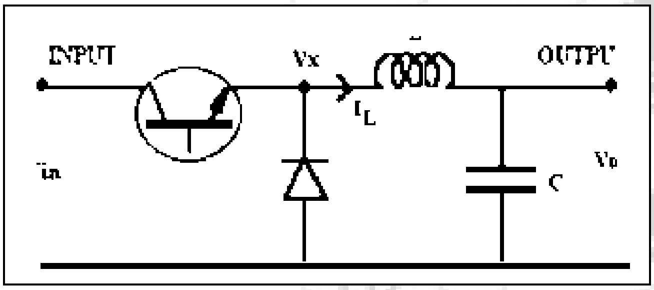


Figure 3.2: buck converter step-down converter

$$V_x\text{-}V_0 = L\frac{di}{dt} \quad (2)$$

For steady state operation the current at the start and end of a period T will not change. To get a simple relation between voltages we assume no voltage drop across transistor or diode while ON and a perfect switch change. Thus during the ON time $V_x=V_{in}$ and in the OFF $V_x = 0$. Thus

$$\text{di}= \int_0^{tON} (Vin - Vo)d\,t + \int_{ton}^{ton+tOff} (-Vo)dt = 0 \quad (3)$$

OR

$$(V_{in}\text{-}V_o)\, t_{on}\text{-}\, V_o\, t_{off} = 0 \quad (4)$$

Which simplifies to and defining "duty ratio" as

$$D = \frac{ton}{T} \quad (5)$$

the voltage relationship becomes Vo=D Vin Since the circuit is lossless and the input and output powers must match on the average Vo* Io = Vin* Iin. Thus the average input and output current must satisfy I_{in} =D Io These relations are based on the assumption that the inductor current does not reach zero.

3.4.1.1 Transition between continuous and discontinuous

When the current in the inductor L remains always positive then either the transistor T1 or the diode D1 must be conducting. For continuous conduction the voltage V_x is either V_{in} or 0. If the inductor current ever goes to zero then the output voltage will not be forced to either of these conditions. At this transition point the current just reaches zero as seen in Figure 3. During the ON time V_{in}-V_{out} is across the inductor is

$$I_L\,(\text{peak}) = (V_{in}\text{-}V_{off})\frac{ton}{L} \quad (6)$$

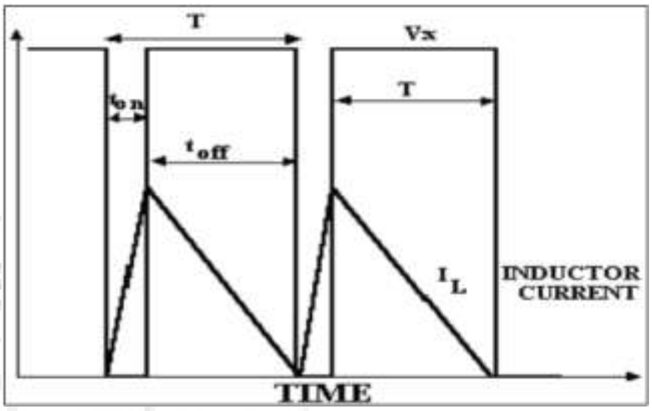


Figure 3.3: transition point of buck converter

If the input voltage is constant the output current at the transition point satisfies

$$I_{out}\,(\text{transition}) = V_{in}\frac{(1-d)d}{2L}T \quad (7)$$

3.4.1.2 Voltage Ratio of Buck Converter (Discontinuous Mode)

As for the continuous conduction analysis we use the fact that the integral of voltage across the inductor is zero over a cycle of switching T. The transistor OFF time is now divided into segments of diode conduction d_{dT} and zero conduction d_{oT}. The inductor average voltage thus gives

$$(V_{in} - Vo)\, DT + (-V_o)\, d_{dT} = 0 \quad (8)$$

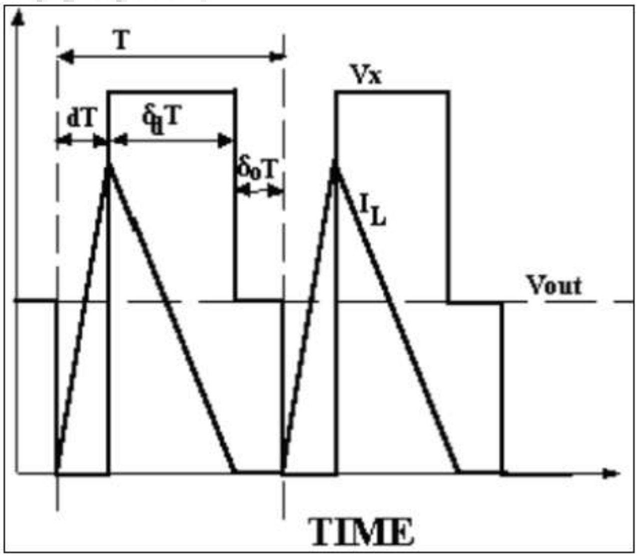


Figure 3.4: Voltage Ratio of Buck Converter (Discontinuous Mode)

$$\frac{Vout}{Vin} = \frac{d}{d+\delta d} \quad (9)$$

When averaged over the conduction times

$$d + \delta d \quad (10)$$

$$I_{out} = \frac{IL(peak)}{2} d + \delta d \quad (11)$$

Considering the change of current during the diode conduction time

$$I_L(peak) = \frac{Vo(\delta d)T}{L} \quad (12)$$

The output voltage is thus given as

$$\frac{Vout}{Vin} = \frac{d^2}{d^2 + \left(\frac{2L\,Iout}{Vin\,T}\right)} \quad (13)$$

Defining k* = 2L / (Vin T), we can see the effect of discontinuous current on the voltage ratio of the

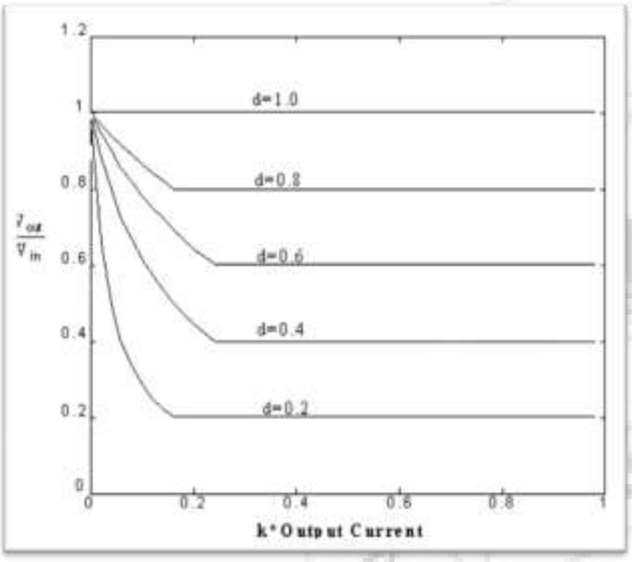


Figure 3.5: effect of discontinuous current on the voltage ratio of the output current

As seen in the figure, once the output current is high enough, the voltage ratio depends only on the duty ratio "d". At low currents the discontinuous operation tends to increase the output voltage of the converter towards V in.

3.4.2 Boost Converter Step-Up Converter

The schematic in Fig. 3.6 shows the basic boost converter. This circuit is used when a higher output voltage than input is required.

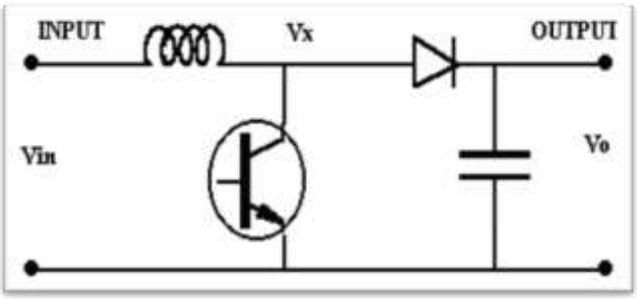


Figure 3.6: Circuit diagram of boost converter

While the transistor is ON $V_x = V_{in}$, and the OFF state the inductor current flows through the diode giving Vx =Vo. For this analysis it is assumed that the inductor current always remains following (continuous conduction). The voltage across the inductor is shown in Fig. 3.7 and the average must be zero for the average current to remain in steady state

$$V_{in}\, t_{on} + (Vin - Vo)\, t_{off} = 0 \quad (14)$$

This can be rearranged as

$$\frac{Vo}{Vin} = \frac{T}{t_{off}} = \frac{1}{1-D} \quad (15)$$

and for a lossless circuit the power balance ensures

$$\frac{Io}{Iin} = (1 - D) \quad (16)$$

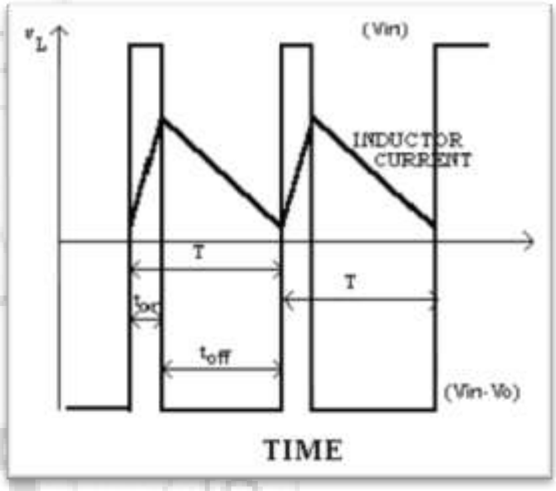


Figure 3.7: The voltage across the inductor

Since the duty ratio "D" is between 0 and 1 the output voltage must always be higher than the input voltage in magnitude. The negative sign indicates a reversal of sense of the output voltage.

3.4.3 Buck-Boost Converter

With continuous conduction for the Buck -Boost converter V x =Vin when the transistor is ON and Vx =Vo when the transistor is OFF. For zero net current change over a period the average voltage across the inductor is zero

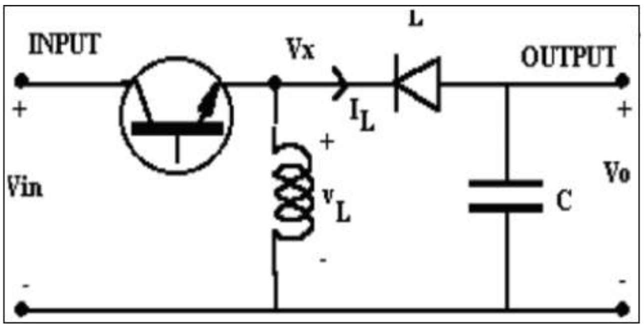


Figure 3.8: Buck-Boost Converter

$$V_{in}\, t_{on} + Vo\, t_{off} = 0 \quad (17)$$

This gives the voltage ratio

$$\frac{Vo}{Vin} = -\frac{D}{(1-D)} \quad (18)$$

and the corresponding current

$$\frac{Io}{Iin} = -\frac{(1-D)}{D} \quad (19)$$

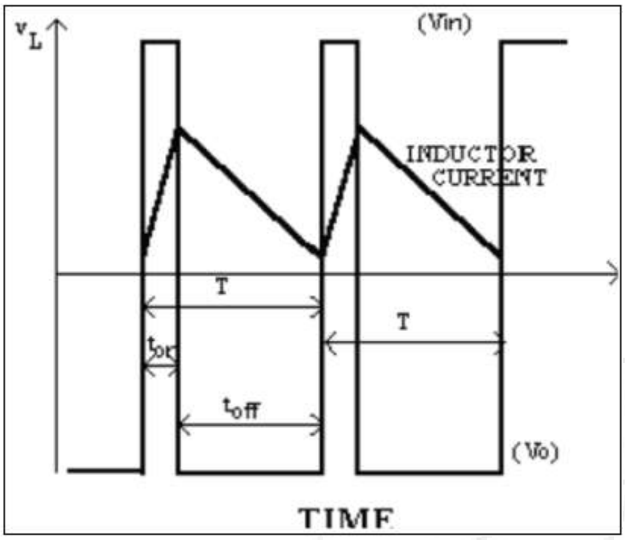


Figure 3.9: voltage across inductor

Since the duty ratio "D" is between 0 and 1 the output voltage can vary between lower or higher than the input voltage in magnitude. The negative sign indicates a reversal of sense of the output voltage.

3.5. Converter Comparison

The voltage ratios achievable by the DC-DC converters are summarized in Fig. 3.10. Notice that only the buck converter shows a linear relationship between the control (duty ratio) and output voltage. The buck-boost can reduce or increase the voltage *ratio with unit gain for a duty ratio of 50%.*

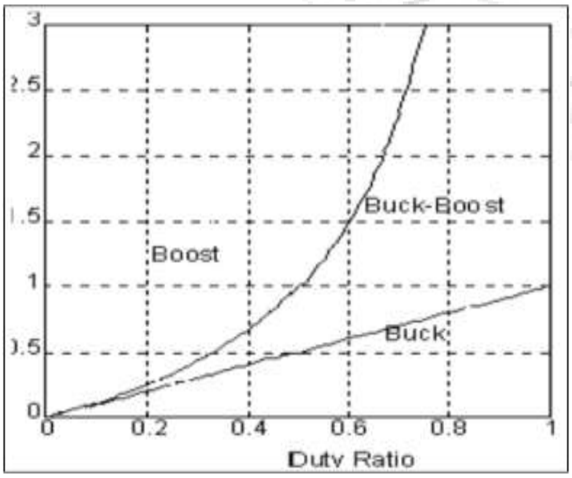


Figure 3.10: Compare of varies converter

3.6 CUK Converter

The buck, boost and buck-boost converters all transferred energy between inputs and output using the inductor, analysis is based of voltage balance across the inductor. The CUK converter uses capacitive energy transfer and analysis is based on current balance of the capacitor. The circuit in Fig. 11 is derived from DUALITY principle on the buck - boost converter

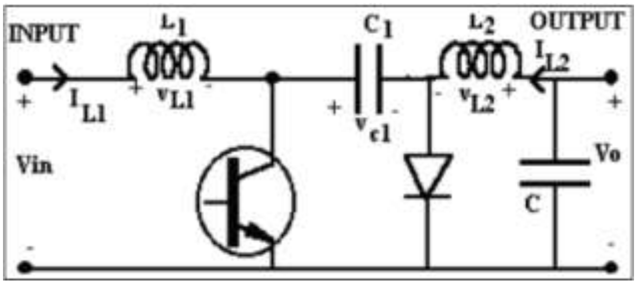


Figure 3.11: cuk converter

If we assume that the current through the inductors is essentially ripple free we can examine the charge balance for the capacitor C1. For the transistor ON the circuit Becomes

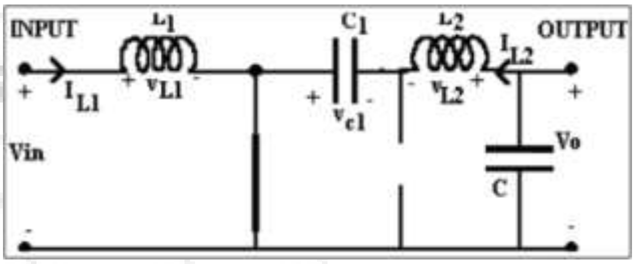


Figure 3.12: Modified cuk converter (circuit 1)

and the current in C1 is IL1. When the transistor is OFF, the diode conducts and the current in C1 becomes

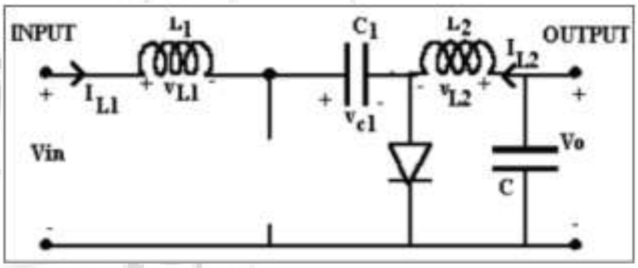


Figure 3.13: modified cuk converter (circuit 2)

Since the steady state assumes no net capacitor voltage rise, the net current is zero Since the steady state assumes no net capacitor voltage rise, the net current is zero which implies

$$\frac{Vo}{Vin} = -\frac{D}{(1-D)} \quad (20)$$

$$I_{L1}t_{on} + (I_{L2})\, t_{off} = 0 \quad (21)$$

$$\frac{I_{L2}}{I_{L1}} = \frac{(1-D)}{D} \quad (22)$$

The inductor currents match the input and output currents, thus using the power conservation rule thus the voltage ratio is the same as the buck-boost converter. The advantage of the CUK converter is that the input and output inductors create a smooth current at both sides of the converter while the buck, boost and buck-boost have at least one side with pulsed current.

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3.7 Isolated DC-DC Converters

In many DC-DC applications, multiple outputs are required and output isolation may need to be implemented depending on the application. In addition, input to output isolation may be required to meet safety standards and / or provide impedance matching. The above discussed DC-DC topologies can be adapted to provide isolation between input and output.

3.8 Fly back Converter

The fly back converter can be developed as an extension of the Buck-Boost converter. Fig 3.13 shows the basic converter; Fig 3.14 replaces the inductor by a transformer. The buck-boost converter works by storing energy in the inductor during the ON phase and releasing it to the output during the OFF phase. With the transformer the energy storage is in the magnetization of the transformer core. To increase the stored energy a gapped core is often used. In Fig 3.15 the isolated output is clarified by removal of the common reference of the input and output circuits.

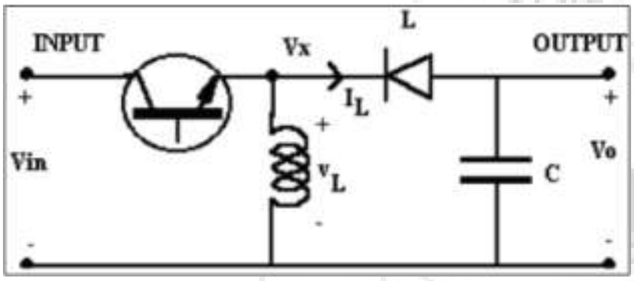

Figure 3.13: basic fly back converter

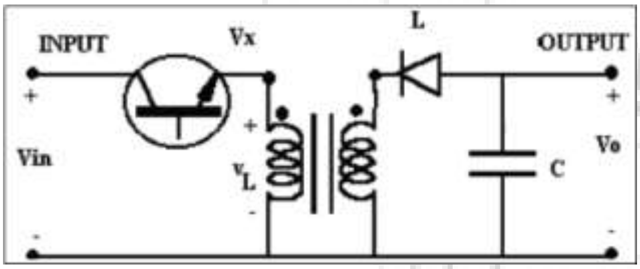

Figure 3.14: replaces the inductor by a transformer

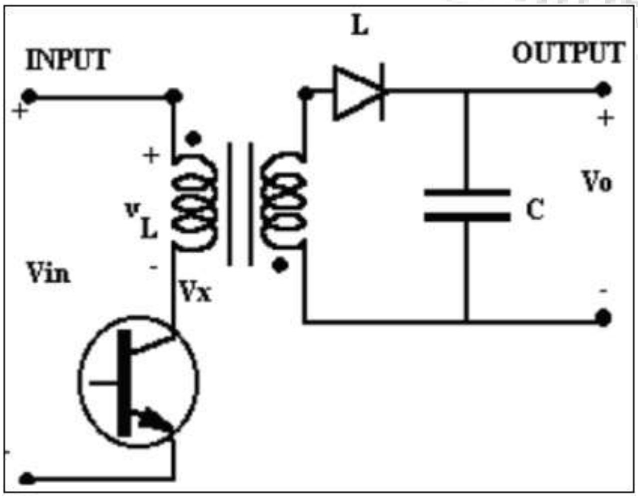

Figure 3.15: The isolated output fly back converter

3.9 Forward Converter

The concept behind the forward converter is that of the ideal transformer converting the input AC voltage to an isolated secondary output voltage. For the circuit in Fig 3.16 when the transistor is ON, V_{in} appears across the primary and then generates

$$V_x = \frac{N1}{N2} V_{in} \quad (23)$$

The diode D1 on the secondary ensures that only positive voltages are applied to the output circuit while D2 provides a circulating path for inductor current if the transformer voltage is zero or negative.

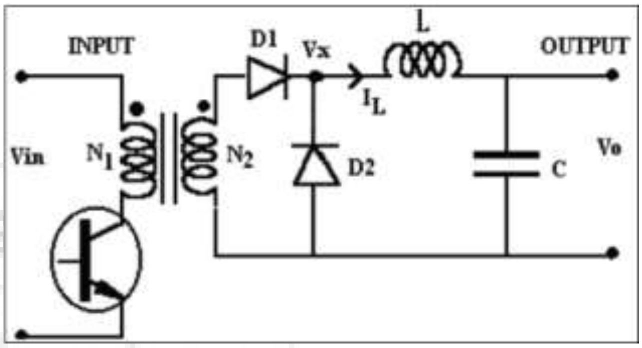

Figure 3.16: circuit diagram of Forward Converter

The problem with the operation of the circuit in Fig 3.16 is that only positive voltage is applied across the core, thus flux can only increase with the application of the supply. The flux will increase until the core saturates when the magnetizing current increases significantly and circuit failure occurs. The transformer can only sustain operation when there is no significant DC component to the input voltage. While the switch is ON there is positive voltage across the core and the flux increases. When the switch turns OFF we need to supply negative voltage to reset the core flux. The circuit in Fig.3.17 shows a tertiary winding with a diode connection to permit reverse current. Note that the "dot" convention for the tertiary winding is opposite those of the other windings. When the switch turns OFF current was flowing in a "dot" terminal. The core inductance act to continue current in a dotted terminal, thus

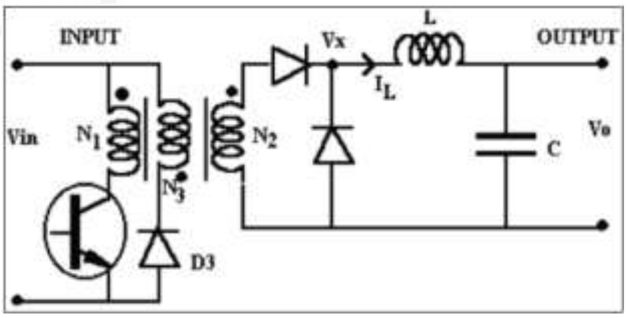

Figure 3.17: tertiary winding with a diode connection to permit reverse current

3.10 Operation and Analysis of the Converter

The switching converters convert one level of electrical signal into another level by switching action. They are popular because of their smaller size and efficiency compared to the other devices. DC-DC converters have a

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very large application area. These are used extensively in personal computers, office equipments; spacecraft power systems, laptop computers, telecommunication equipments, computer peripherals, and consumer electronic devices to provide dc voltages as well as DC motor drives. The wide variety of circuit topology ranges from single transistor buck, boost and buck-boost converters to complex configurations comprising two or four devices and employing soft-switching techniques to control the switching losses.

There are some other methods of classifying dc-dc converters. One of them depends on the isolation property of the primary and secondary portion. The isolation is usually made by a transformer, which has a primary portion at input side and a secondary at output side. Feedback of the control loop is made by another smaller transformer. Therefore, output is electrically isolated from input. This type includes Fly-back dc-dc converters and SMPS for PC power supply with an additional ac-dc bridge rectifier in used. However, in portable devices, since transformer and other off-chip components is very big and costly, so non-isolation dc-dc converters are more preferred.

DC-DC converters are used in power electronics circuits to convert an unregulated DC input voltage to a regulated or variable DC output voltage. The circuit's main commercial application is in systems that require a stable and regulated DC output voltage. Switching devices are normally operated at very high frequency range from few hundred kilohertz.

Switching converters use power semiconductor devices to operate in either the on line or the off line. Since the recent advances in semiconductor technology allow the capabilities of very high switching speed and high power handling, it is possible to convert DC to DC with higher efficiency and occur better regulation using a switching regulator.

DC-DC converters store energy in an inductor, capacitor or both during operation. This energy is then consumed to the load over a period of time. This consumption of the stored energy is reached efficiently by varying the charging time for the energy storage device, depending on the load, for every time period. The charging time period corresponds to the switching action of the power converter, which is controlled by an external circuitry.

Depending on whether or not an output transformer is used, high-frequency DC-DC switching converters are classified as isolated or none isolated. For isolated DC-DC converters, the main types of converters are as follows: buck, boost and buck-boost. However, in most of the practical applications, isolation is required for the DC-DC converters, which include some widely used topologies, such as the fly back, forward, push-pull, half-bridge and full bridge converters.

3.11 Controller for DC-DC Converter

In a DC-DC converter application, it is desired to obtain a constant output voltage in spite of disturbances in input voltage and load current. Therefore, the idea behind the use of negative feedback for control is to build a circuit that automatically adjusts the duty cycle as needed to obtain the desired output voltage with high accuracy, regardless of disturbances in input and load. A block diagram of a feedback system is shown in Figure The output voltage V(t) is measured using a "sensor" with transfer function of H(s) The sensor output V(t) H(s) is compared with a voltage reference $V_{ref}(s)$ The error between V(t) H(s) and $V_{ref}(s)$ is feed to compensator that amplifies error signal and makes the output voltage regulated around reference voltage. In practice, the error is usually nonzero. A compensator gain Ge (s) helps to obtain a small error and improve the stability and performance of the system. The PWM (pulse width modulator) modulator is used to generate "digital" pulse width feed into the switch of converter. The pulse width changes with the comparator output voltage. Vc(t)

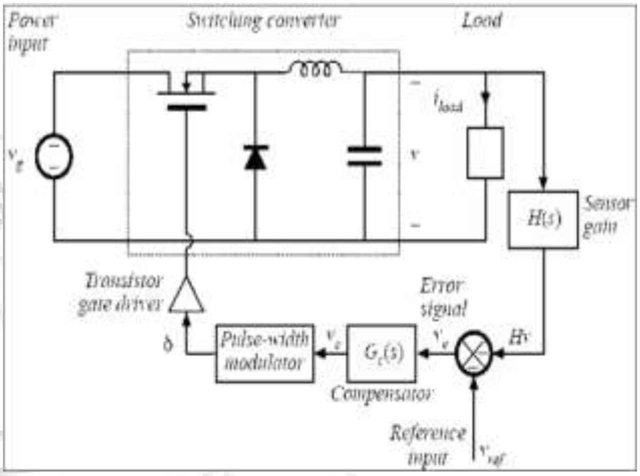

Figure 3.18: Feedback loop for switching of converter

The traditional scheme for controllers of DC-DC converters based on duty ratio changed this is known as analog implementation schemes. The above mentioned control method based on analog techniques offer robust control, but suffer from same limitations such as sensitivity to noise and temperature change. So this we have moved towards digital control schemes, which offer multi useful benefits. PWM controllers for switching power supplies offer a number of advantages like as a reduction of the number of passive components, implementation of more advanced control algorithms and additional processing option.

Generally, there are several implementation approaches for digital controllers today, which include Microprocessor/ DSP's (Digital Signal Processors), Field Programmed Gates Array and Custom IC Design.

The half-bridge (HB) DC-DC converter is an attractive topology for middle-power level applications due to its simplicity. There are two conventional control schemes for the HB DC-DC converter, namely symmetric control and asymmetric (complimentary) control. A HB DC-DC converter with a Current Doublers Rectifier (CDR) is suitable for high-current low-voltage applications, since the CDR structure has lower conduction loss compared to the center-tap rectifier.

In this thesis a PWM and isolated transformer DC-DC converter model is established for the full bridge but 3 diode and three inductor DC-DC converters with three phase inverter while taking into consideration the parasitic DC parameters. Based on the DC model, design issues are provided with both symmetric FB and asymmetric FB DC-DC converters. Also, utilizing the LC filter for reduce the switching losses and THD.

3.12 Inverters

Inverters are circuits that convert dc to ac. We can easily say that inverters transfer power from a dc source to an ac load. The aim is to create an ac voltage when only a dc voltage source is available. A variable output voltage can be obtained by varying the input dc voltage and maintaining the gain of the inverter constant. On the other hand, if the dc voltage is fixed & not controllable, a variable output voltage can be obtained by varying the gain of the inverter, which is normally accomplished by pulse-width-modulation (PWM) control within the inverter. The inverter gain can be defined as the ratio of the ac output voltage to dc input voltage.

3.11.1 Classification of Inverter

Basically Inverters are two types:
- Single-phase inverter
- Three-phase inverter

3.11.2 Different types of inverter:

- Full-bridge inverter
- Half-bridge inverter
- Pulse-width modulated inverter
- Current-source inverter
- Variable DC-link inverter
- Boost inverter
- Resonant pulse inverter
- Multilevel inverter
- Six-step inverter

3.11.2.1 Full-Bridge Converter

The full bridge converter is the basic circuit that converts dc to ac. An ac output is synthesized from a dc input by closing and opening the switches in the appropriate sequence. The output voltage V0 can be +Vdc, -Vdc, or zero depending on the switch is closed. We have to make sure that switches are opened and closed in sequence otherwise short circuit could be happened.

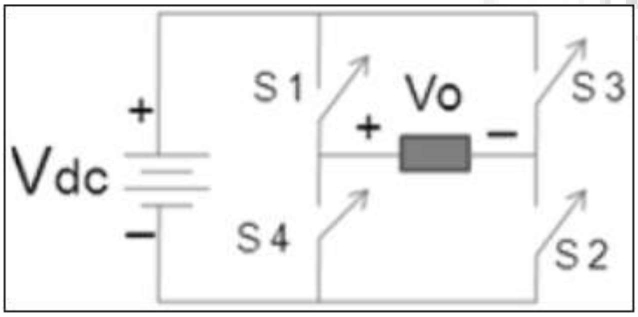

Figure 3.19: full-bridge converter

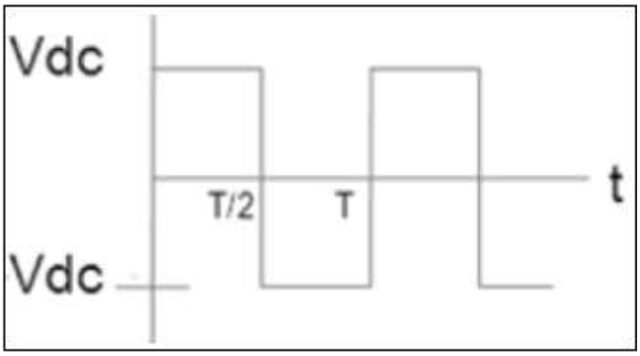

Figure 3.20: waveform of full bridge inverter

Note that S1 and S4 should not be closed at the same time, nor should S2 and S3, otherwise, a short circuit would exist across the dc source. Real switches don't turn on or off instantaneously. Therefore, transition times must be accommodated in the control of the switches. Overlap of the switch "on" times will result in a short circuit, sometimes called a "shoot-through" fault, across the dc voltage source. The time allowed for switching is called "blanking" time.

3.11.2.2 Half-Bridge Inverter

The half- bridge converter can be used as an inverter. This circuit can also be used as dc power circuit. In the half bridge inverter the number of switches is reduced to two by dividing the dc source voltage into two parts with the capacitors. Each capacitor will be the same value and will have voltage $V_{dc}/2$ across it. When s1 is closed the load voltage is –Vdc/2.when s2 is closed, the load voltage is $V_{dc}/2$.thus, a square-wave output or a bipolar pulse-width modulated output, as described in the following section can be produced. The voltage across an open switch is twice the load voltage, or Vdc .as with the full bridge inverter blanking time for the switches is required to prevent a short circuit across the source, and feedback diodes are required to provide continuity of current for inductive load.

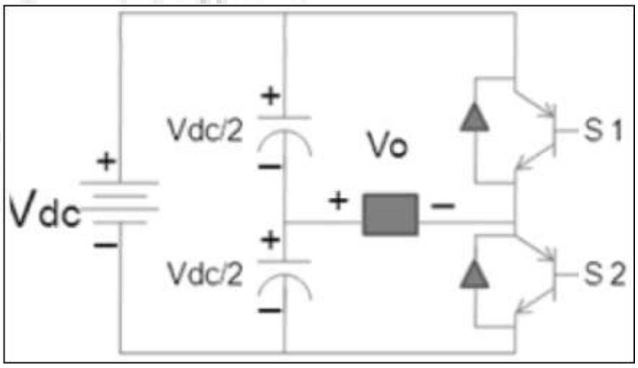

Figure 3.21: half-bridge inverter

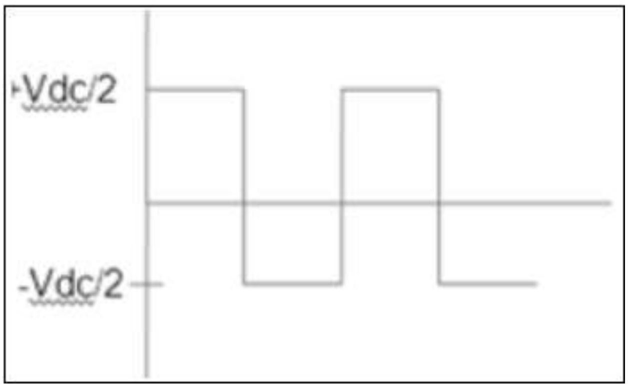

Figure 3.22: waveform of half-bridge inverter

3.11.2.3 Pulse-Width Modulation Inverter

To design an Inverter, many power circuit topologies and voltage control methods are used. The most important aspect of the Inverter technology is the output waveform. To filter the waveform (Square wave, quasi sine wave or Sine wave) capacitors and inductors are used. Low pass filters, are used to reduce the harmonic components.

In pulse width modulated (PWM) inverters, the input DC voltage is essentially constant in magnitude and the AC output voltage has controlled magnitude and frequency. Therefore the inverter must control the magnitude and the frequency of the output voltage. This is achieved by PWM of the inverter switches and hence such inverters are called PWM inverters.

For square-wave inverters, the input DC voltage is controlled in order to adjust the magnitude of the output AC voltage. Therefore the inverter has to control only the frequency of the output voltage. The output AC voltage has a waveform similar to a square-wave. Square wave switching method will produce more harmonic contents in inverter output compared to pulse width modulation switching technique.

SPWM or sinusoidal pulse width modulation is widely used in power electronics to digitize the power so that a sequence of voltage pulses can be generated by the on and off of the power switches. The pulse width modulation inverter has been the main choice in power electronic for decades, because of its circuit simplicity and rugged control scheme. SPWM switching technique is commonly used in industrial applications. SPWM techniques are characterized by constant amplitude pulses with different duty cycle for each period. The width of this pulses are modulated in order to obtain inverter output voltage control and to reduce its harmonic content. Sinusoidal pulse width modulation or SPWM is the most common method in motor control and inverter application. Conventionally, to generate the signal, triangle wave as a carrier signal is compared with the sinusoidal wave, whose frequency is the desired frequency. The reason for using PWM techniques is that they provide voltage and current wave shaping customized to the specific needs of the applications under consideration.

By using PWM techniques, the frequency spectra of input waveforms can be changed such that the major non-fundamental components are at relatively high frequency and also to reduce the switching stress imposed on the power switching devices. Most PWM is generated by comparing a reference waveform with a triangular carrier waveform signal. However, the reference waveform may come in various shapes to suit the converter topology, such as sine wave and distorted sine wave. A sinusoidal waveform signal is used for PWM in DC to AC converter where it is used to shape the output AC voltage to be close to a sine wave. The commonly used techniques are:

1. Single pulse width modulation
2. Multiple pulse width modulation
3. Sinusoidal pulse width modulation
4. Modified pulse width modulation
5. Phase displacement control
6. Bipolar switching

3.11.2.3.1 Single Phase Pulse Width Modulated Inverters

The dc-ac converter, also known as the inverter, converts dc power to ac power at desired output voltage and frequency. The dc power input to the inverter is obtained from an existing power supply network or from a rotating alternator through a rectifier or a battery, fuel cell, photovoltaic array or magneto hydrodynamic generator. The filter capacitor across the input terminals of the inverter provides a constant dc link voltage. The inverter therefore is an adjustable-frequency voltage source. The configuration of ac to dc converter and dc to ac inverter is called a dc-link converter.

Inverters can be broadly classified into two types, voltage source and current source inverters. A voltage–fed inverter (VFI) or more generally a voltage–source inverter (VSI) is one in which the dc source has small or negligible impedance. The voltage at the input terminals is constant. A current–source inverter (CSI) is fed with adjustable current from the dc source of high impedance that is from a constant dc source.

A voltage source inverter employing thyristors as switches, some type of forced commutation is required, while the VSIs made up of using GTOs, power transistors, power MOSFETs or IGBTs, self commutation with base or gate drive signals for their controlled turn-on and turn-off.

A standard single-phase voltage or current source inverter can be in the half-bridge or full-bridge configuration. The single-phase units can be joined to have three-phase or multiphase topologies. Some industrial applications of inverters are for adjustable-speed ac drives, induction heating, standby aircraft power supplies, UPS (uninterruptible power supplies) for computers, HVDC transmission lines, etc.

3.11.2.3.2 Voltage Control in Single - Phase Inverters

The schematic of inverter system is as shown in Figure 2.1, in which the battery or rectifier provides the dc supply to the inverter. The inverter is used to control the fundamental voltage magnitude and the frequency of the ac output voltage. AC loads may require constant or adjustable voltage at their input terminals, when such loads are fed by inverters, it is essential that the output voltage of the inverters is so controlled as to fulfill the requirement of the loads. For example if the inverter supplies power to a magnetic circuit, such as a induction motor, the voltage to frequency ratio at the inverter output terminals must be kept constant. This avoids saturation in the magnetic circuit of the device fed by the inverter. The various methods for the control of output voltage of inverters can be classified as:

(a) External control of ac output voltage
(b) External control of dc input voltage
(c) Internal control of the inverter.

The first two methods require the use of peripheral components whereas the third method requires no external components.

3.11.2.3.3 Pulse Width Modulation Control

The fundamental magnitude of the output voltage from an inverter can be controlled to be constant by exercising control within the inverter itself that is no external control circuitry is required. The most efficient method of doing this is by Pulse Width Modulation (PWM) control used within the inverter. In this scheme the inverter is fed by a fixed input voltage and a controlled ac voltage is obtained by adjusting the on and the off periods of the inverter components. The advantages of the PWM control scheme are;

a) The output voltage control can be obtained without addition of any external components.
b) PWM minimizes the lower order harmonics, while the higher order harmonics can be eliminated using a filter.

The disadvantage possessed by this scheme is that the switching devices used in the inverter are expensive as they must possess low turn on and turn off times, nevertheless PWM operated are very popular in all industrial equipments. PWM techniques are characterized by constant amplitude pulses with different duty cycles for each period. The width of these pulses are modulated to obtain inverter output voltage control and to reduce its harmonic content. There are different PWM techniques which essentially differ in the harmonic content of their respective output voltages, thus the choice of a particular PWM technique depends on the permissible harmonic content in the inverter output voltage.

3.11.2.3.4 Sinusoidal-Pulse Width Modulation (SPWM)

The sinusoidal PWM (SPWM) method also known as the triangulation, sub harmonic, or sub oscillation method, is very popular in industrial applications and is extensive. The SPWM is explained with reference to Figure 2.2, which is the half-bridge circuit topology for a single-phase inverter.

For realizing SPWM, a high-frequency triangular carrier wave is compared with a sinusoidal reference of the desired frequency. The intersection of and waves determines the switching instants and commutation of the modulated pulse. The PWM scheme is illustrated in Figure 2.3 a, in which vis the peak value of triangular carrier wave and v that of the reference, or modulating signal. The figure shows the triangle and modulation signal with some arbitrary frequency and magnitude. In the inverter of Figure 2.2 the switches and are controlled based on the comparison of control signal and the triangular wave which are mixed in a comparator. When sinusoidal wave has magnitude higher than the triangular wave the comparator output is high, otherwise it is low.

The comparator output is processes in a trigger pulse generator in such a manner that the output voltage wave of the inverter has a pulse width in agreement with the comparator output pulse width. The magnitude ratio of curves called the modulation index () and it controls the harmonic content of the output voltage waveform. The magnitude of fundamental component of output voltage is proportional to. The amplitude of the triangular wave is generally kept constant.

To satisfy the Kirchhoff's Voltage law (KVL) constraint, the switches on the same leg are not turned on at the same time for each leg of the inverter. This enables the output voltage to fluctuate between 2dVand -2dV

3.11.2.3.5 Single-Phase Inverters

A single-phase inverter in the full bridge topology is as shown in Figure 2.5, which consists of four switching devices, two of them on each leg. The full-bridge inverter can produce an output power twice that of the half-bridge inverter with the same input voltage. Three different PWM switching schemes are discussed in this section, which improve the characteristics of the inverter. The objective is to add a zero sequence voltage to the modulation signals in such a way to ensure the clamping of the devices to either the positive or negative dc rail; in the process of which the voltage gain is improved, leading to an increased load fundamental voltage, reduction in total current distortion and increased load power factor.

3.12 Filters

3.12.1 Passive Filters

Passive implementations of linear filters are based on combinations of resistors (R), inductors (L) and capacitors (C). These types are collectively known as passive filters, because they do not depend upon an external power supply and/or they do not contain active components such as transistors. Inductors block high-frequency signals and conduct low-frequency signals, while capacitors do the reverse. A filter in which the signal passes through an inductor, or in which a capacitor provides a path to ground, presents less attenuation to low-frequency signals than high-frequency signals and is therefore a low-pass filter. If the signal passes through a capacitor, or has a path to ground through an inductor, then the filter presents less attenuation to high-frequency signals than low-frequency signals and therefore is a high-pass filter. Resistors on their own have no frequency-selective properties, but are added to inductors and capacitors to determine the time-constants of the inductors and capacitors are the reactive elements of the filter. The number of the circuit, and therefore the frequencies to which it responds. An element determines the order of the filter. In this context, an LC tuned circuit being used in a band-pass or band-stop filter is considered a single element even though it consists of two components. At high frequencies (above about 100 megahertz), sometimes the inductors consist of single loops or strips of sheet metal, and the capacitors consist of adjacent strips of metal. These inductive or capacitive pieces of metal are called stubs.

3.12.1.1Single element types

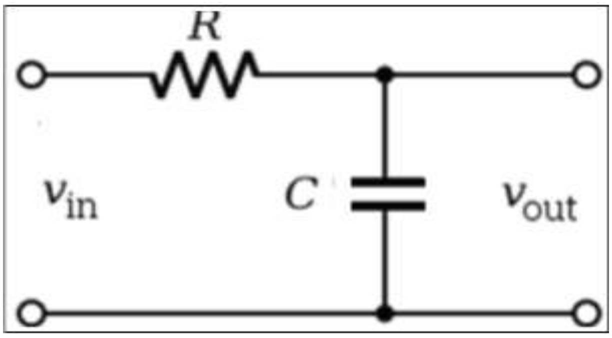

Figure 3.23: Single Element Passive Filters

The simplest passive filters, RC and RL filters, include only one reactive element, except hybrid LC filter which is characterized by inductance and capacitance integrated in one element.

L filter
An L filter consists of two reactive elements, one in series and one in parallel.

T and π filters

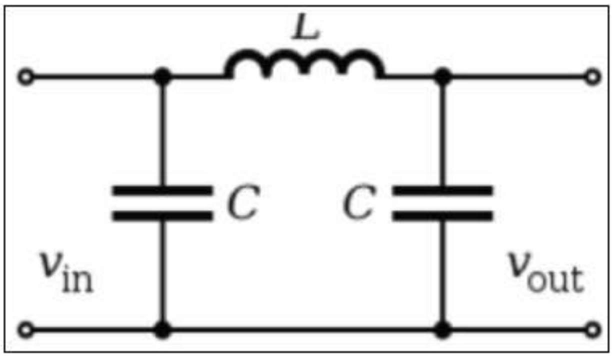

Figure 3.24: low pass π filter

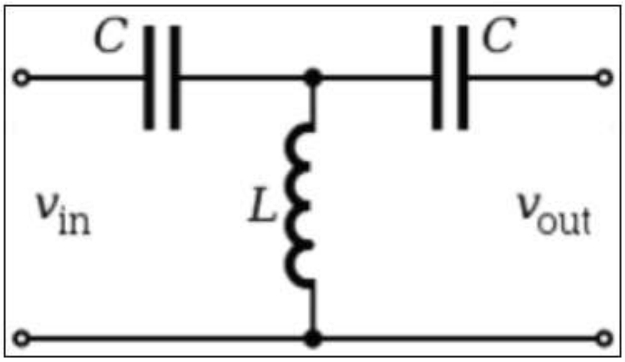

Figure 3.25: high pass T filter

Three-element filters can have a 'T' or 'π' topology and in geometries, a low-pass, high-pass, band-pass, or band-stop characteristic is possible. The components can be chosen symmetric or not, depending on the required frequency characteristics. The high-pass T filter has very low impedance at high frequencies, and very high impedance at low frequencies. That means that it can be inserted in a transmission line, resulting in the high frequencies being passed and low frequencies being reflected. Likewise, for the low-pass π filter, the circuit can be connected to a transmission line, transmitting low frequencies and reflecting high frequencies. Using m-derived filter sections with correct termination impedances, the input impedance can be reasonably constant in the pass band.

3.12.1.2 Multiple element types
Multiple element filters are usually constructed as a ladder network. These can be seen as a continuation of the L, T and π designs of filters. More elements are needed when it is desired to improve some parameter of the filter such as stop-band rejection or slope of transition from pass-band to stop-band.

3.12.2 Active filters
Active filters are implemented using a combination of passive and active (amplifying) components, and require an outside power source. Operational amplifiers are frequently used in active filter designs. These can have high Q factor, and can achieve resonance without the use of inductors. However, their upper frequency limit is limited by the bandwidth of the amplifiers.

3.12.3 Other filter technologies

3.12.3.1 Digital filters
Digital signal processing allows the inexpensive construction of a wide variety of filters. The signal is sampled and an analog-to-digital converter turns the signal into a stream of numbers. A computer program running on a CPU or a specialized DSP (or less often running on a hardware implementation of the algorithm) calculates an output number stream. This output can be converted to a signal by passing it through a digital-to-analog converter. There are problems with noise introduced by the conversions, but these can be controlled and limited for many useful filters. Due to the sampling involved, the input signal must be of limited frequency content or aliasing will occur.

4. Matlab® Simulink Model and Simulink Results

4.1 MATLAB® Simulink Model

A750W, 5V/150A proto type model of proposed DC–DC converter has been built and its schematic diagram is shown in Fig.4.1.The bock diagram of is developed in three stages namely development of power circuits, control circuits and protection circuits.

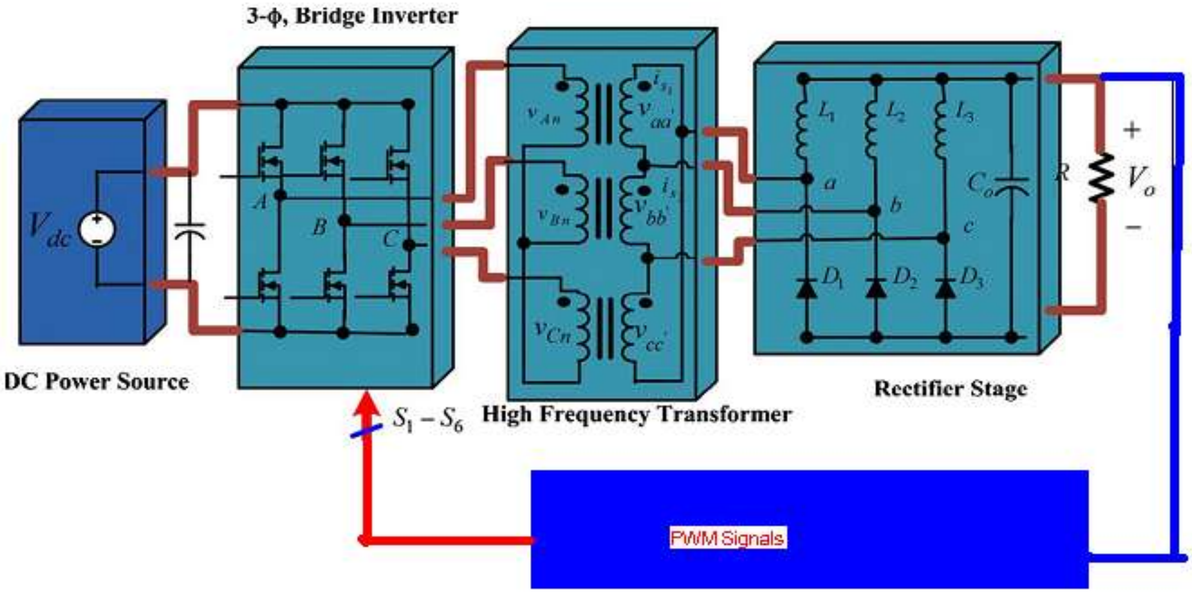

Figure 4.1: block diagram of high frequency isolated three-phase dc–dc converter.

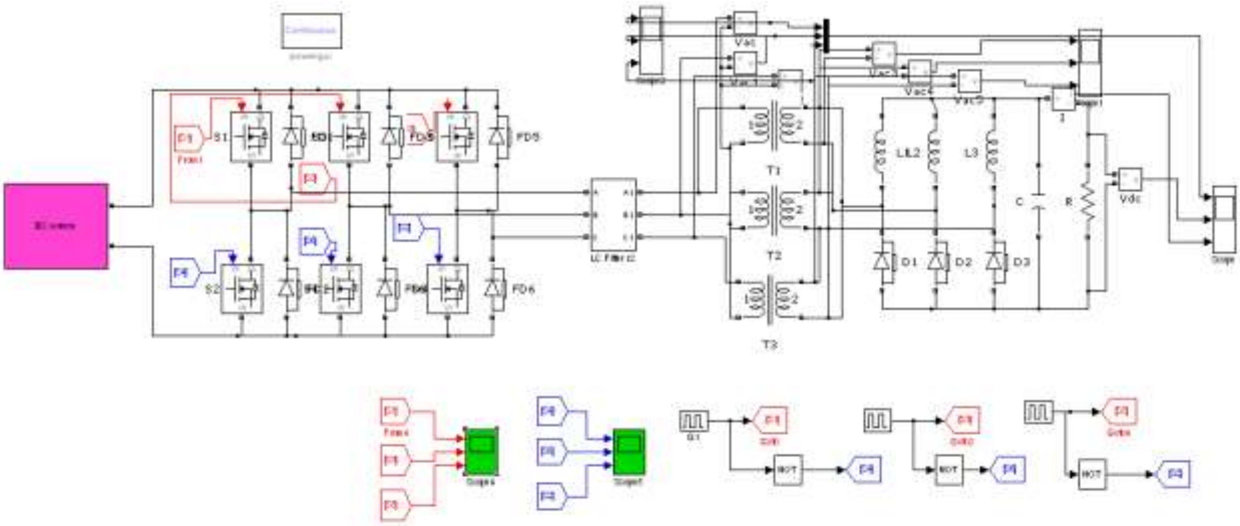

Figure 4.2: MATLAB/Simulink model of high frequency isolated three-phase dc–dc converter with pulse control

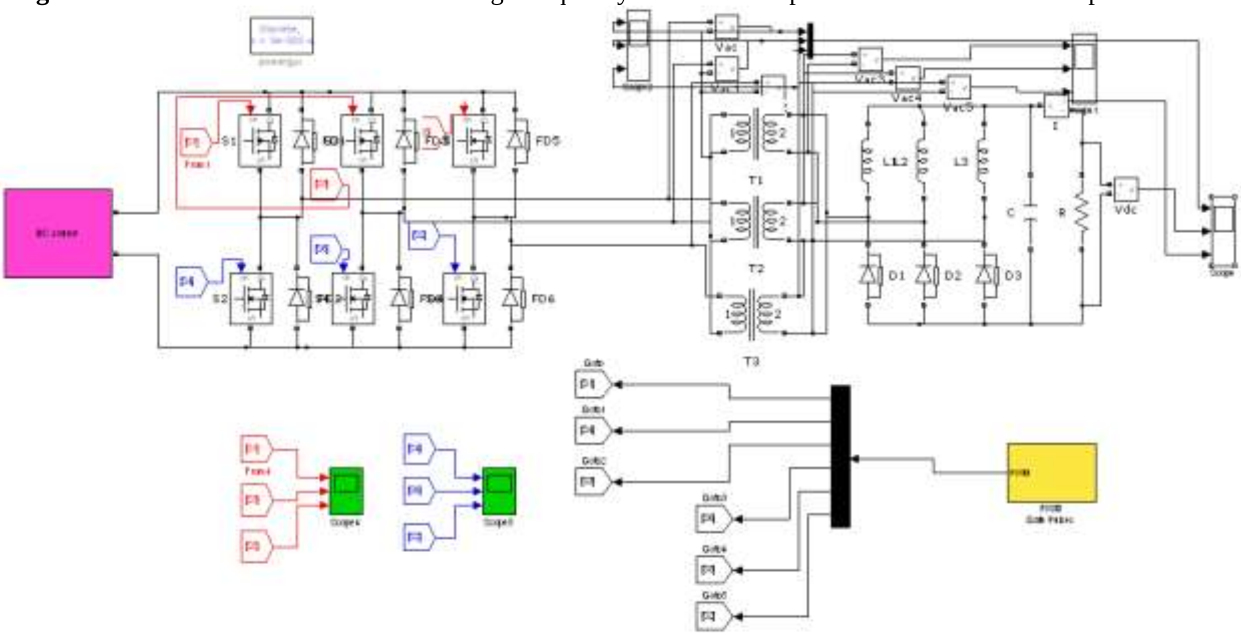

Figure 4.3: MATLAB/Simulink model of high frequency isolated three-phase dc–dc converter with PWM pulse control

4.2 Result analysis

Case I High frequency isolated three-phase dc–dc converter with pulse control

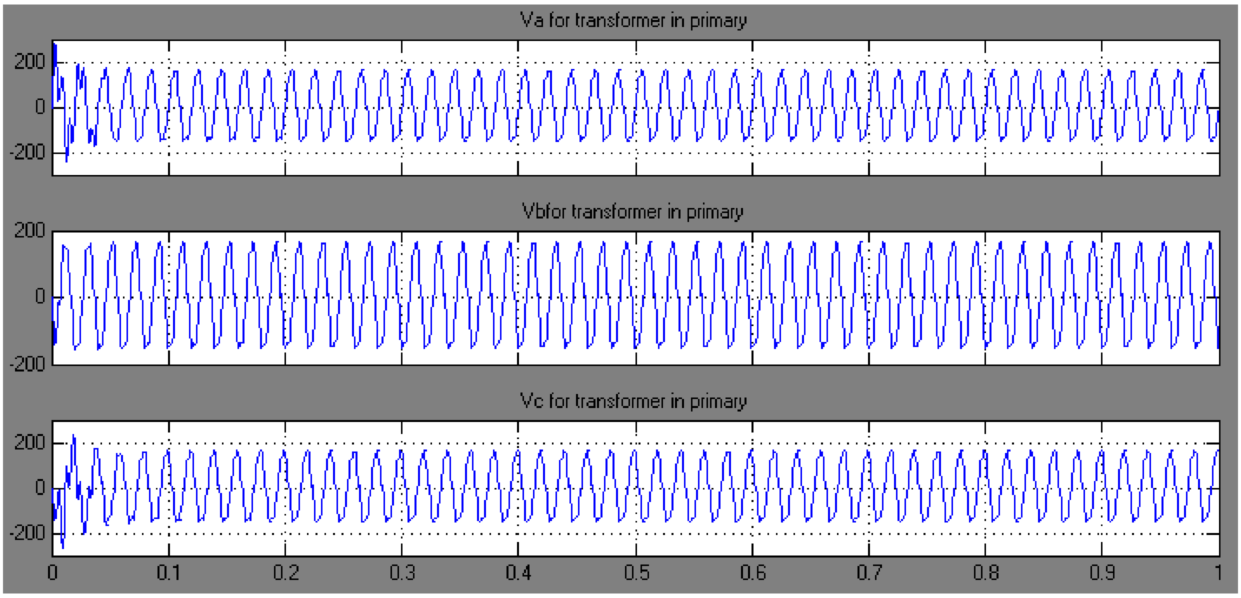

Figure 4.4: Voltage waveform for isolated three-phase dc–dc converter with pulse control in transformer primary side

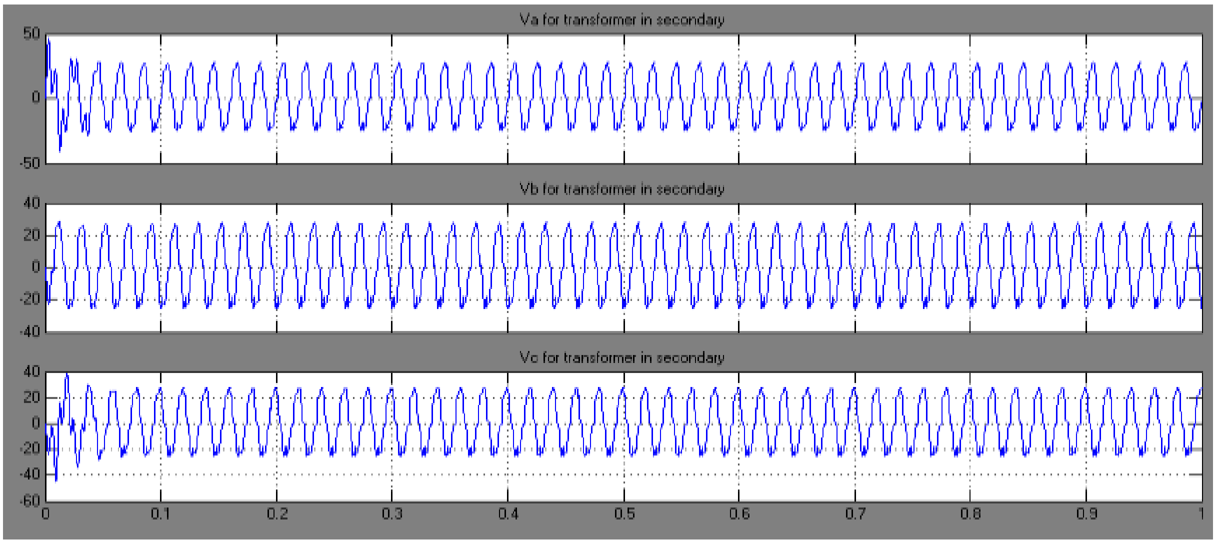

Figure 4.5: Voltage waveform for isolated three-phase dc–dc converter with pulse control in transformer secondary side

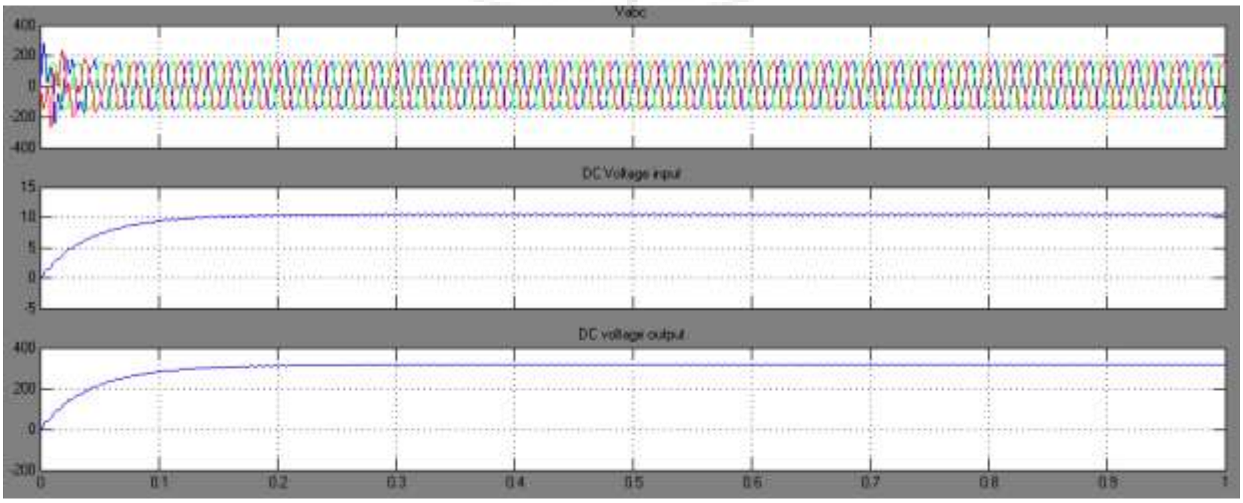

Figure 4.6: waveform for Vabc and Vdc in input side and Vdc output side isolated three-phase dc–dc converter

Case II High frequency isolated three-phase dc–dc converter with PWM pulse control

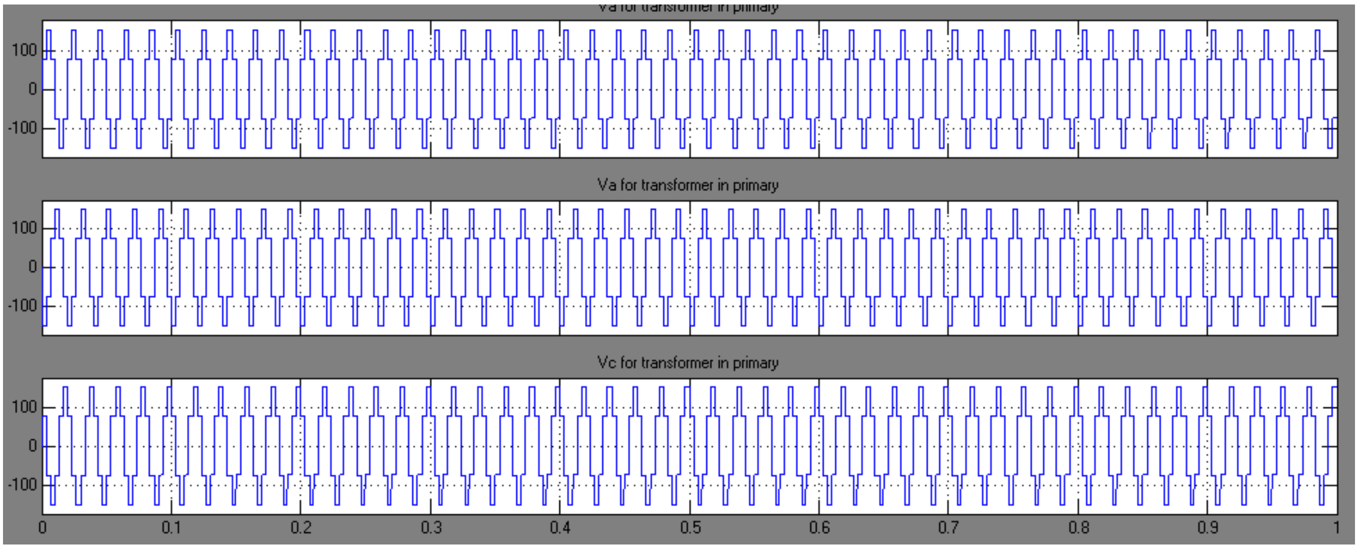

Figure 4.7: Voltage waveform for isolated three-phase dc–dc converter with pulse control in transformer primary side

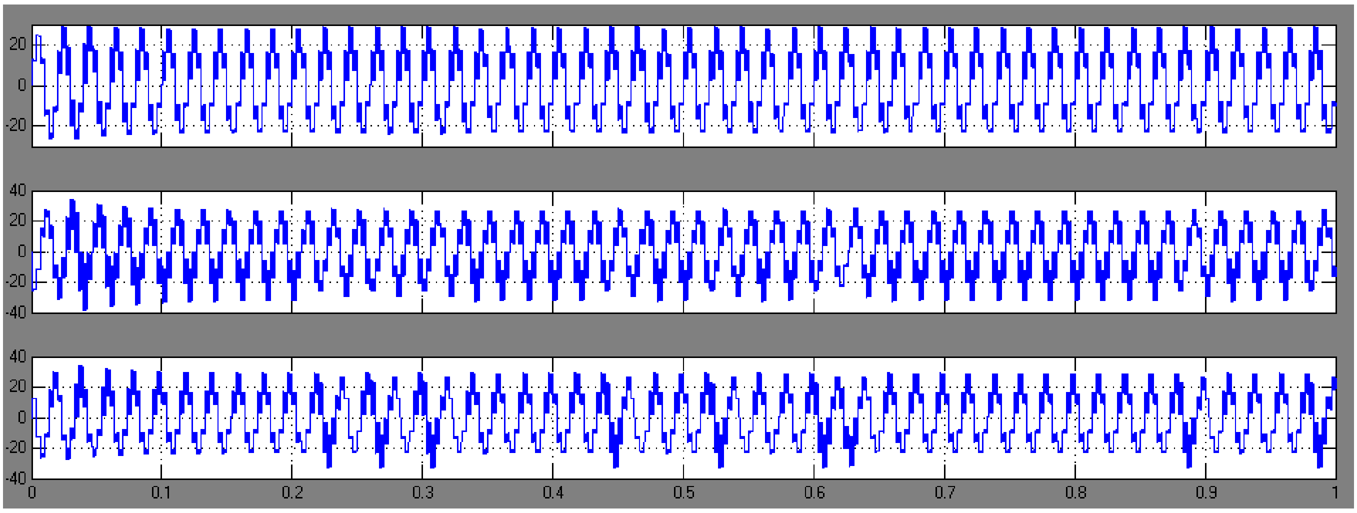

Figure 4.8: Voltage waveform for isolated three-phase dc–dc converter with pulse control in transformer secondary side

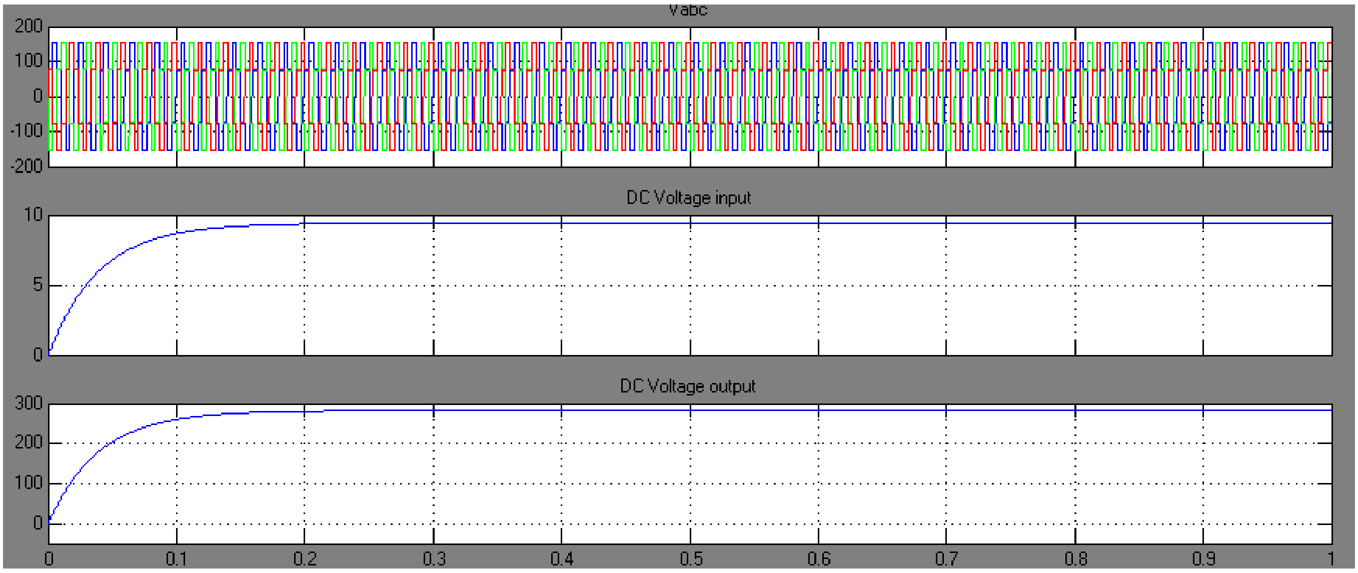

Figure 4.9: Waveform for Vabc and Vdc in input side and Vdc output side isolated three-phase dc–dc converter with PWM signals

5. Conclusion and Future Scope

Based on the literature review, simulations results and the performed experiments, following points can be concluded:

High frequency isolated three-phase DC–DC converter is suggested to reduce size, weight and improved dynamic response. In this work we developed dynamic simulation with high frequency dc to dc converter. we consider two case one high frequency isolated three-phase dc–dc converter with pulse control MATLAB model and discuss about the simulation results and other hand high frequency isolated three-phase dc–dc converter with PWM pulse control MATLAB model and discuss about the simulation results and comparison both system results.

Future Scope of Work

1) The operation of the converter, considered for the grid connection, can also be investigated for continuous conduction mode.
2) We have considered an application in which fuel cell, solar energy, is integrated high frequency isolated three-phase dc–dc converter
3) FC stacks integration with various other high frequency isolated three-phase dc–dc converter and study the behavior of a closed-loop controller with ANN, Fuzzy logic.