Capacitor Diode Clamped LLC Resonant Converter for Current Limiting Harmonic Approximation

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Abstract- *In this paper, the analysis and design of LLC resonant converters with capacitor – diode clamp current limiting harmonic approximation is being presented. Moreover, here the resonant capacitor of an LLC converter is split into clamped and non clamped portions. The fundamental harmonic approximation (FHA) based equivalent circuit model, is derived for the converter to accurate the current limiting characteristic under overloading condition. Here the two diodes are replaced by capacitors to obtain smoothened output. From this we get advantages like high gain, less output ripple and minimum conduction loss. The converter voltage-gain and voltage current characteristics under different overload condition and operating frequencies are predicted using proposed model.*

   Keywords — *llc,dc-dc converter,capacitor –diode clamp*

I.   INTRODUCTION

In recent years, the converter plays a major role in electrical field. Converters are electrical device that convert AC to DC, DC to AC, DC to DC and AC to AC. Thus the converters are more essential for all electrical devices. To convert AC to DC source we need a rectifier circuit. A rectifier is a device which rectifies the given AC input source and supplies DC input to the load. Rectifier can be half bridge or full bridge circuit. Here in the proposed system we have used half bridge rectifier with two diodes and two capacitors. Thus the capacitors will minimize the ripples and smoothens the signals from disturbances. Resonant Converter is a type of a converter which is well-known for its attractive features like Smooth waveform, High efficiency and High power density. It is based on resonant current oscillation. It is mainly used to reduce / eliminate the switching losses. Comparing the other converter resonant converter has many advantages. Resonant converters are classified into four types[2]. The resonant converters like series resonant converter, parallel resonant converter, series-parallel resonant converter and multi resonant converter which are used to overcome the switching losses[3].
These three converters have big penalty for wide input range design, to achieve the switching property over zero-voltage the converter has to work on the negative slope of DC characteristics. High switching loss will occur at high input voltage so that the series resonant converter (SRC), parallel resonant converter (PRC) and series to parallel resonant converters (SPRC) are not suitable for DC-DC application, and also could not be optimized at high input voltage. So that in LCC Resonant converter, which is two capacitors and one inductor converter, the inductor (L) has been changed into capacitor(C) and capacitor has been changed into inductor (L) in such a way LLC Resonant converter is built. It has more attention in recent years for its high efficiency, high operating capability and simple in structure. LLC Resonant topology allows zero voltage switching of the main switches, therefore switching losses are minimized and increased by boosting efficiency.
LLC Resonant converter acts very similar to series resonant converter because of its lack of understanding in characteristics of this converter.LLC Resonant Converters will have some special characteristics which are more suitable for DC/DC application. The main advantage of series resonant converter is simple in nature and has high efficiency from full load to reduced load.
Clamp Circuit is a special type of circuit that is used to limit or clamp the output voltage to a specific range[12]. Clamping is done through the use of diodes.
Diode clamp consists of a diode, this allows the circuit to conduct from only one direction and it does not allow the current to flow in reverse direction[13]. Here the capacitor diode clamp is presented for the making the clamp voltage to move in a rail [5]. It controls the signal exceeding from the reference value, and a capacitor which provides the DC offset from the stored charge. Here the clamp circuit are split up into capacitors and is fed with the clamping voltages as the input. The voltage of the capacitors is clamped to the output of the transformer voltage which sends the clamped voltage to be definite and allows the current limiting performance to be gained.
The Fundamental harmonic approximation is determined in resonance converter which is based on the equivalent circuit. It has been derived that the converter   is used to determine the current limiting characteristics under over load condition[16]. The resonant converter will give the current and the

voltage wave form with pure sinusoidal wave at fundamental frequency and will neglect the higher order harmonics[15].

The aim of the project is to limit the current in over load condition using LLC Series Resonant Converter[1]. Thus for overload protection we need current sensor which helps to detect the over load condition. The overload condition of the current will be limited without using feedback mechanism. Thus the theoretical and practical analysis of the circuit is discussed in the following chapter
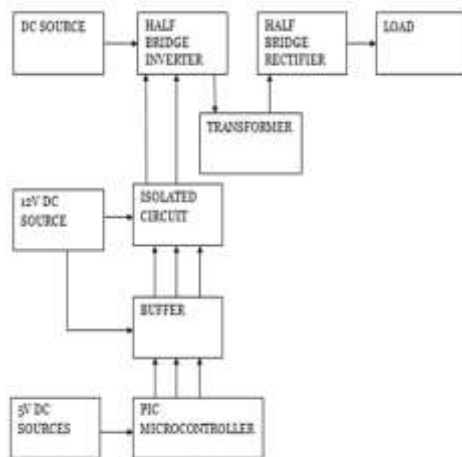
II.   BLOCK DIAGRAM

Figure 1:LLC resonant convertor with capacitor diode clamp

The block diagram of LLC resonant converter with capacitor diode clamp current limiting circuit consist of[4],
- PIC microcontroller
- Buffer
- Isolated circuit
- Half bridge inverter
- Transformer
- Half bridge rectifier

The DC input source of 5V is given to the controller circuit which consist of PIC microcontroller and buffer IC. The buffer IC amplifies the current and improves the current gain. The output of buffer is given to the isolator circuit.
The isolated circuit will isolate the signal and transfer it to the half bridge inverter; here two diode and two capacitor are constructed so it has been called the half bridge inverter. The inverter will convert the DC source into AC source. Thus the AC source which has been inverted by the half bridge inverter is sent to the transformer.

Here the isolated transformer has been constructed, thus the isolated which helps the circuit to be protected because the isolated transformer will isolate the circuit when fault occurs, thus the fault side will stop working and the other side of the

circuit will be working. The fault side will not damage the circuit. This is the advantage of the isolated transformer. Thus the transformer is step down and the voltage is bucked. The bucked voltage is transfer to the half bridge rectifier[17].

The rectifier converts the AC into DC source, here the half bridge rectifier will rectify the given signal and converts the AC into DC source[7]. The capacitor in the circuit will filter the ripple in the circuit and send the signal to the load
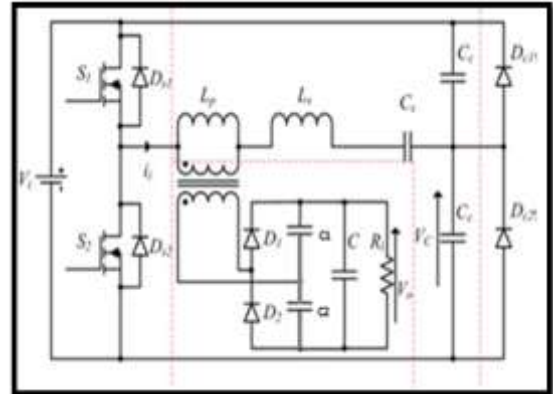
III.   POWERCIRCUIT

Figure 2: Power circuit

A system which limits and control the current in overload condition is been shown in the proposed model. The circuit is designed to limit the current at over load condition. The system is constructed by a half bridge LLC resonant converter with capacitor diode clamp[8]. There are four operational parts:
- Two mosfet switches S_1 and S_2 which forms a DC chopper.
- Inductors and capacitors (L_P, L_S, L_C and C_S and C_P) resonant tank. The inductor and capacitors are magnetically moulded to the transformer.
- The diode D_1 and D_2, capacitors C_1 and C_2 will form transformer, bridge rectifier and output filter.
- A clamp circuit is formed by connecting two diode D_1 and D_2 will clamp V_c voltage to the input voltage V_i.
- Here the switch S_1 and S_2 will conducts and change DC source into a square wave form.

Thus the wave form is been passed though the resonant tank and changed into AC waveform. When this wave passes they give isolated DC output[10].
Here the capacitor will reduce the ripple and smoothen the wave, thus voltage has been stabilized and they charge and discharges the diode D_{c1} and D_{C2} is used for limiting the current. Thus in normal state the diodes D_{C1} and D_{c2} does not conduct[14].

Here the capacitor C_c is connected parallel and series with the capacitor C_s[5].

IV. CONSTRUCTION

The construction of the proposed system consists of four main divisions,

A. Controller circuit

Figure 3: Controller circuit

The controller circuit consists of PIC microcontroller (AT85C51), current buffer IC, diodes IN4007, capacitor, crystal oscillator, regulator (7805) and a resistor.
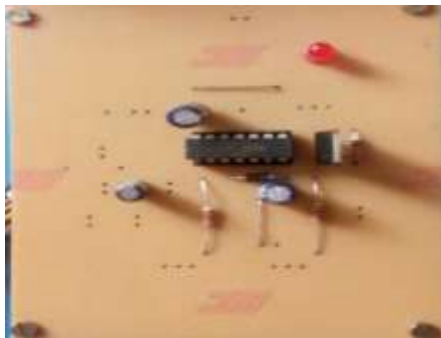
B. Isolator circuit

Figure 4: Isolator circuit

The isolator circuit consists of a gate driver, regulator 7812, resistor, capacitor and diodes IN4007.
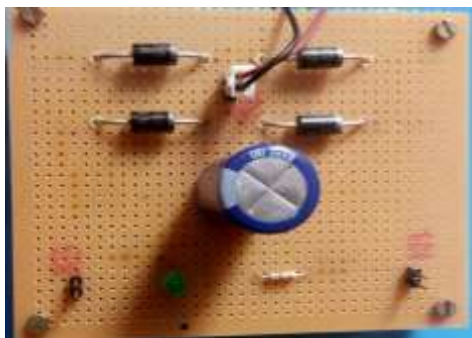
C. Converter circuit

Figure 5: Converter circuit

The converter circuit consists of capacitor, diode IN5408 and resistor
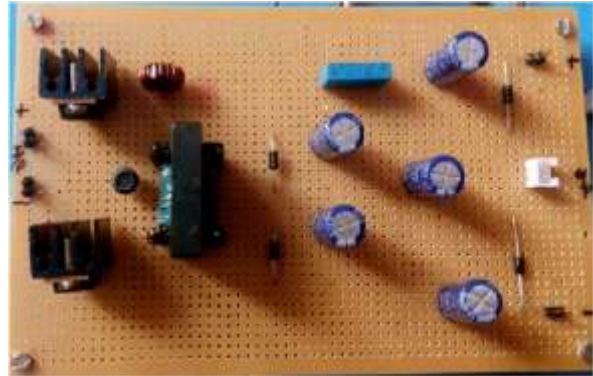
D.Power circuit

Figure 6: Power circuit

The power circuit consist of two MOSFET switches IRF 840 (800v 5amps), a isolated transformer made up of ferro magnetic material a combination of iron and magnets, inductors, capacitors and diodes IN4007.

V.ANALYSIS OF CIRCUIT LAYOUT

Figure 7: Analysis of Circuit Layout

The transformer (T1) has the rating of 45/230 volts which is given as an input to the converter circuit. The transformer (T2) has the rating of 15/230 volts which is given to controller circuit and isolator circuit. The transformer (T2) feds 5volts regulated dc supply to the controller circuit. The controller circuit has a pic micro controller, a buffer ic and a regulator. A 40 pin pic micro controller (AT89C51) is low power and high performance, CMOS 8-bit microcontroller with 4k bytes of flash programmable and erasable read only memory (PEROM). The regulated voltage 5v is given to the supply voltage(VCC).the ground (GND)is grounded, XTAL1 gives input clock operating circuit,XTAL2 gives the output from oscillator amplifier here

crystal oscillator is used to drive the external clock source. The out of the microcontroller is given to the buffer which will amplify and increases the current gain. The output of the controller circuit and the regulated voltage of 12 v is given to the isolator circuit. When a fault occurs in the controller circuit or in power circuit the isolator circuit will isolate them. The resistors used in the isolator circuit will reduce the noise.

Now the transformer (T2) gives voltage of 45volt to the converter circuit, the converter circuit will transform the AC voltage DC voltage and supplies to the power circuit.

V SIMULATION RESULTS

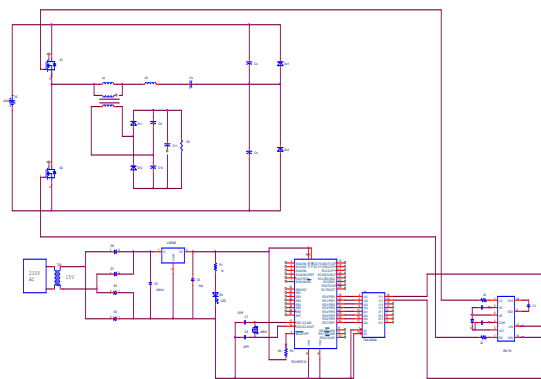The connection of the circuit in shown in the figure:

Figure 8: Simulation Circuit

A. Input waveform

When 230V AC input is given to the transformer of range 45V, the converter circuit is fed with 44V AC. The converter circuit converts ac to dc and it is given to power circuit. CRO is connected to the positive and the negative terminal to the input side of the circuit a sinusoidal wave form is produced.
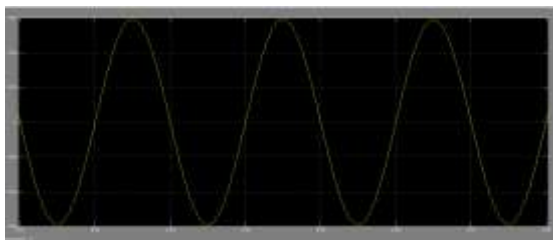

Figure 9: Input Voltage Waveform

B. Output waveform

The output from the converter is given to power circuit; the CRO is connected to the positive andnegative terminal of power circuit. The output waveform is bucked to 14v. Thus the output waveform gives the ripple less waveform using capacitor in the power circuit. The ripple is reduced using capacitor. As shown in the figure6b.
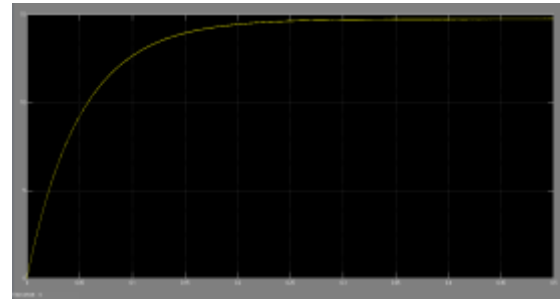

Figure 10:Output Voltage Waveform

VI CONCLUSION

Thus overload condition of the current can be limited using LLC resonant converter with capacitor-diode clamp[9]. The clamped circuit is designed in such a way that it limits the current at once the current is overloaded. The capacitor in the power circuit is to minimise the ripple which is produced, increases the current gain and conduction lose is reduced and harmonic is been reduced. The isolator circuit is used when the current is overloaded it separates the circuit into two half, Thus the circuit is protected. The output is bucked and the experimental measurement shows that the output current is successfully reduced from 44V to 17A. The output voltage is bucked and given to the load, here we have given DC motor to be connected to the load, the motor is operated in the bucked input voltage.

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