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Simulation Analysis of Resonant Converters

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***Abstract*— The conflict between high frequency and switching losses is always observed. Power converters that operate near high frequencies suffers from high switching losses that results into low efficiency. There is one key to this ,which nothing but replacement of switch with the resonating switch. The paper spotlights the performance analysis for various resonant converters which helps in choosing an appropriate resonant converter pertaining to an application.**

***Index Terms*— High efficiency, High frequency, Resonant Converter, Output regulation.**

I. INTRODUCTION

Power electronics simply is an art of efficiently converting and conditioning electric power using electronic switches. However ,it is tough [1]. To retrieve an efficient conversion of electrical energy two forms of converters are available, They are pulse width modulated (PWM) converters and resonant converters. The traditional switch-mode power converters are mostly “hard switched”. These converters give controlled output voltage including change in width of gate. At end of switching cycle there will be stress on switch , resulting steep switching loss in the device. protecting circuit is a prerequisite, which complicates circuit . power converters that run at greater frequencies are preferable, as high frequency operating condition reduces the circuit components size. But , it also rises switching losses which in turn affects efficiency. To avoid this ,the switch of SMPS must be of replaced with "resonant switch" , which generates required shape of output waveform ,by exploiting the resonances of capacitances , inductances of circuit in a fashion that there will not be any voltage, current at switch during its operation The rapid improvement in semi conductor devices has pointed out the invention of switching devices like MOSFET. They can reduce the bulk nature of power supply systems. The energy impairment in a switch can be described by two terms they are switching losses and conduction losses .The losses during on time are conduction losses. These depend on on-state voltage depilation. .As the name itself suggests that the losses during switching are switching losses , these also vary from one converter to other as they differ from topography. Some of the losses create stresses to power semiconductors which in long term may affect power supply reliability. Appropriate picking of switches can reduce these inimical effects. For this one must the characteristics of switches, such as:
1)conduction capacity during on-time,
2) Acceptable reverse voltage,
3) switching characteristics,
4) price.

By considering these facts many circuit topographies are proposed. one among them is resonant converters .Resonant converters, have both switching and resonant circuits. Natural properties of resonant circuit depresses switching losses. so, resonant topographies gathered the attention of researchers. In RC resonating circuit will be composed by inductors and capacitors ,leading to zero switching current at on ,off instants, known as ZCS. so, the switching will be considerably reduced, thereby making switching frequency larger. The possible large switching frequency not only depends on switch ,but it also relays on control strategy , gating circuits and Appropriate picking of circuit components. The resonant converters are categorized as below.

II .CLASSIFICATION OF RESONANT CONVERTERS

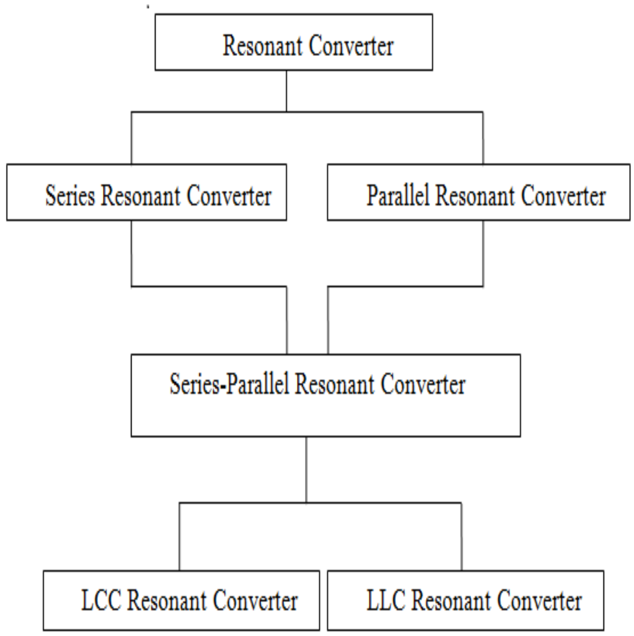

Fig. 1. Classification of Resonant Converter

SERIES RESONANT CONVERTER:

Series Resonant Converter: The nomenclature reveals that in series resonant converter the resonating inductor Lr ,resonating capacitor Cr will be connected in series, thus creating a tank. Impedance of resonating tank varied by varying frequency of input voltage .The dc gain is below 1 .[3] The frequency range will be from 200HZ to 100Khz[4] .

The circuit of SRC is shown as below:

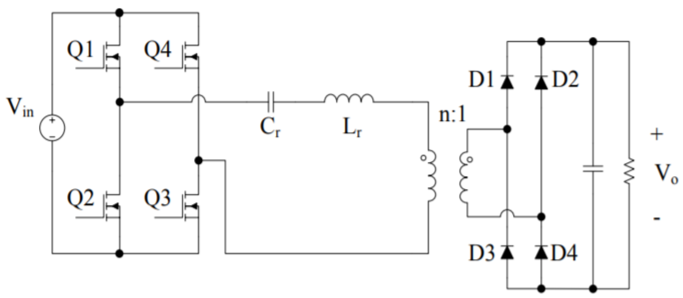

Fig. 2.Series Resonant Converter

The simulation circuit of full bridge SRC is as shown below:

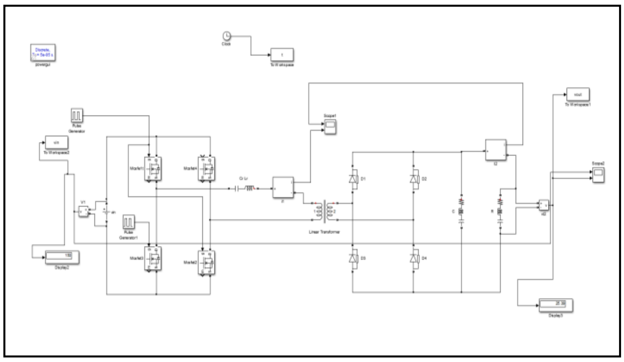

Fig. 3.Simulation circuit of SRC.

The voltage conversion of series-resonant converter with input voltage 150v to 25.5v can be shown below.

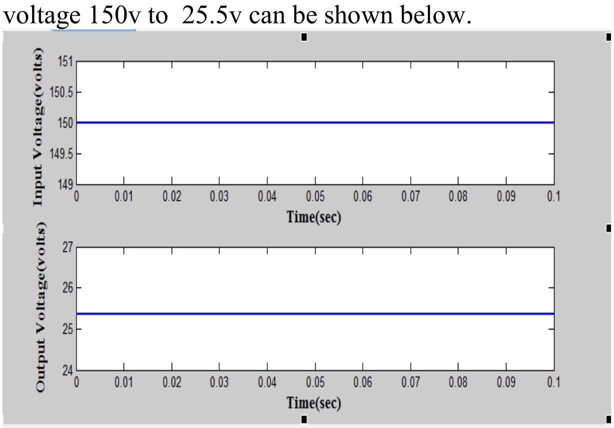

Fig. 4. Input and Output plots of SRC.

DC characteristics for SRC shown below

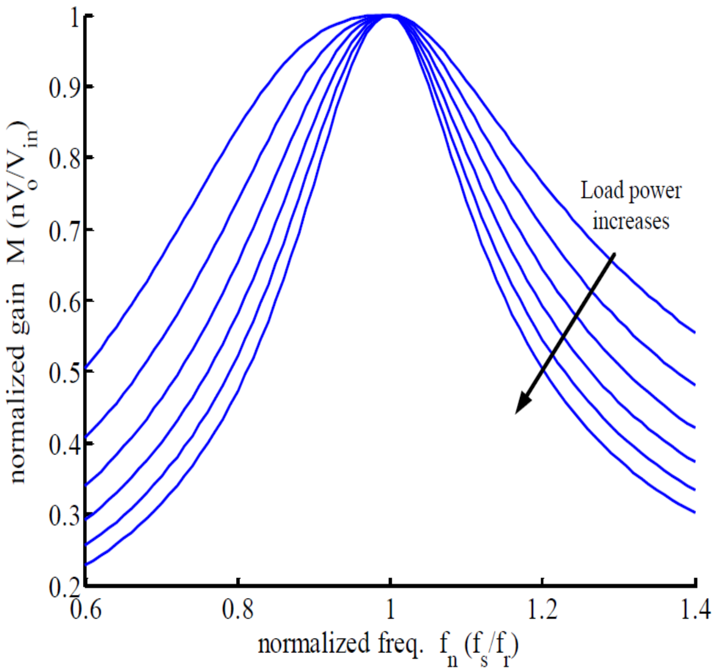

Fig. 5.The DC characteristics for SRC.

The plot reveals that for simple loads the gain curves are less steep, which means that to regulate the high input voltage, wide ranges of frequency is essential for simple loads than to the heavy loads.

According to theory, the zero load regulation is impossible for SRC as the gain curve will be flat for zero load condition. Besides this, at large frequencies , switching depletion during turn off will be high, so SRC is not apt to wide ranges of input and load applications.

Since a resonant circuit lies in between the inverter ,load, the harmonics in current are negligible. So, fundamental analysis can be applied.

Advantage

1) Easy Implementation.
2)Low conduction losses at light load.
3) Short-circuit protection.

Disadvantages:

1) Voltage regulation will be poor at light load.
2) Because of high ripple content in capacitor current it does not suits for low voltage and peak powers.
3) Only voltage step-down characteristic.

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PARALLEL RESONANT CONVERTER:

In parallel resonant converter also tank circuit is in series. As load is in parallel , hence parallel resonant converter. It can perform both step-UP and step-Down operations. An additional inductor is incorporated in secondary for resonance .

The circuit diagram of PRC is shown as below:

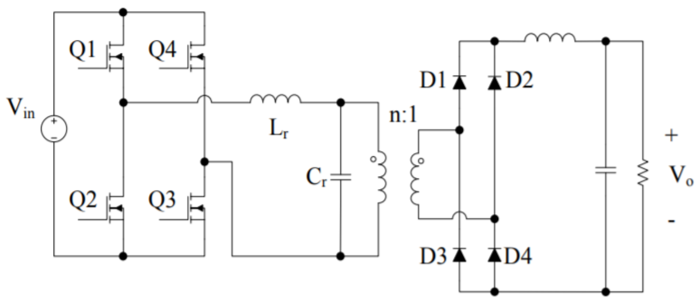

Fig. 6. Cicuit of PRC.

The simulink diagram for full bridge parallel step-up resonant circuit is as shown below.

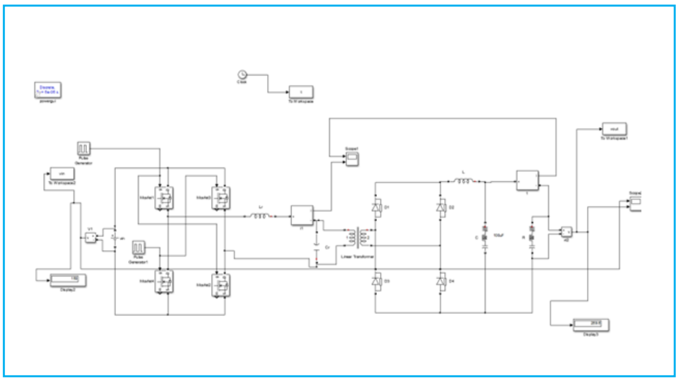

Fig. 7. simulation circuit of PRC.

For a given input of 150v the output of step-Up PRC can be displayed below as 251v.

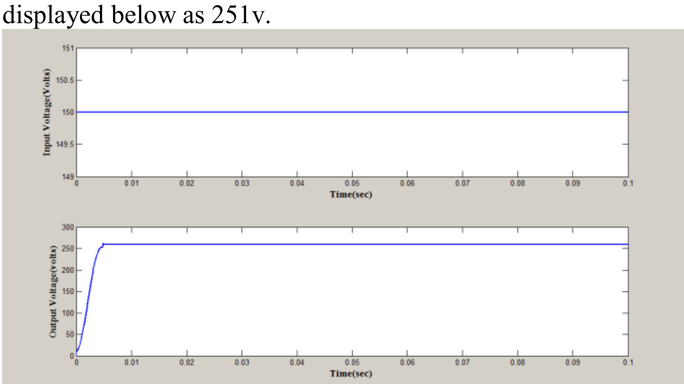

Fig. 8. Input - Output plots of PRC

DC characteristics for PRC are displayed below:

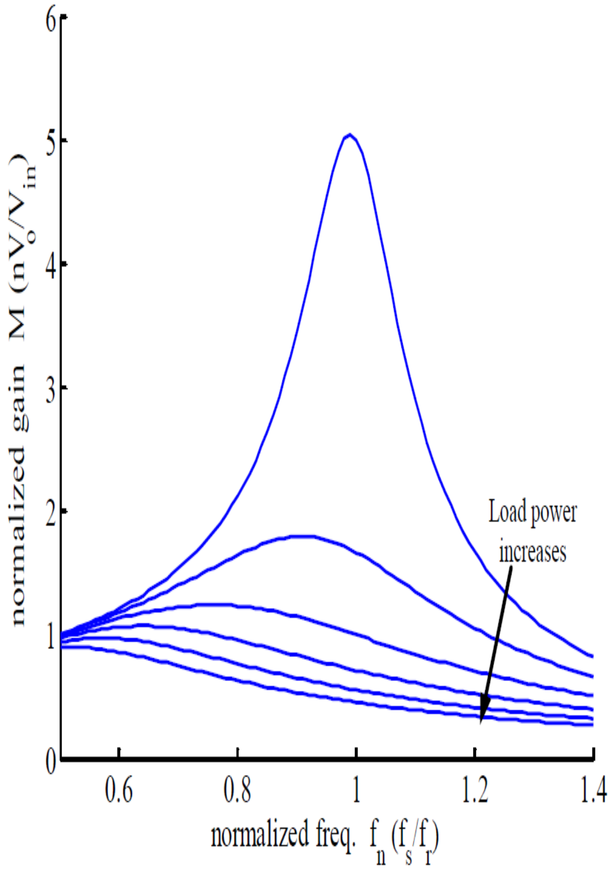

Fig. 9 .The DC characteristics for PRC.

. In PRC ZVS is resulted if converter is confined to peak frequency region and little higher to it. But as the maximum frequency depends on load and tank parameters ,it varies and moves to less gain as load proceeds. For same ranges of input , load frequency required for regulation of voltage lies in narrow range. The slope of dc characteristics is steeper to light loads. PRC suffers with circulating current resulting into more conduction losses , less efficiency near light loads.

These converters can produce continuously regulated current ,so it gives short circuit protection. A PRC regulates output in between fully loaded condition to un loaded condition by working for frequency larger than resonance. Also it fulfills short circuit requirements. But Conduction losses in semiconductor do not vary with load.

Advantage :Load does not impact current.

Disadvantage**:** Low efficiency at simple loaded condition.

SERIES-PARALLEL RESONANT CONVERTER:

Tank circuit for SPRC comprises three components which have two possibilities. They are two inductors one capacitor or one inductor two capacitors .An additional inductance will be added here also to obtain resonance .It is advantageous ,being the merger of series, Parallel resonant converters.

LCC Resonant Converter:

LCC RC is capable of regulating the resultant voltage by capacitor in parallel .As frequency of switching is far from resonating frequency ,it cannot optimizes voltage near large input. The topology will have two capacitors , one inductor as resonating parameters.

The circuit of LCC RC is as shown below:

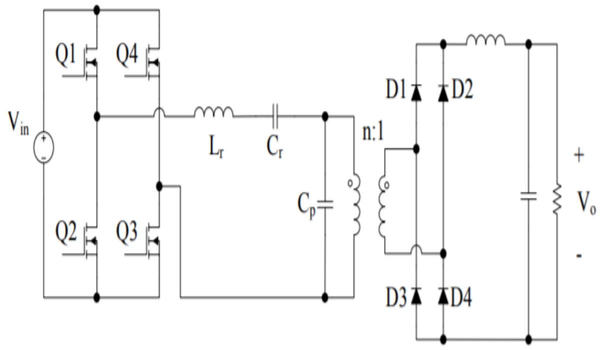

Fig. 10. Circuit of LCC RC.

The simulink diagram for LCC converter is displayed below.

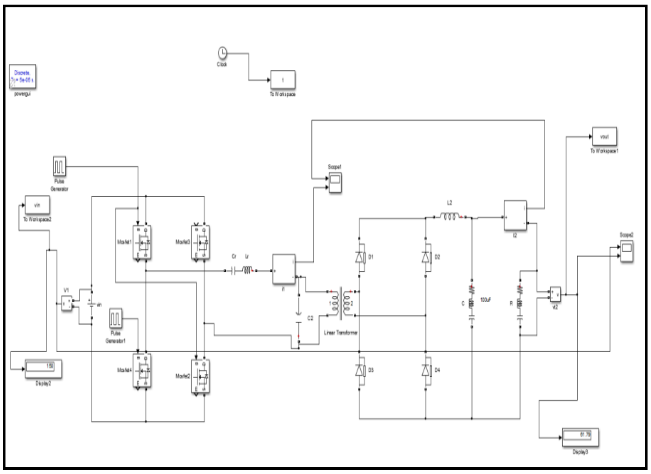

Fig. 11.simulation circuit for SPRC

The input ,out plots of LCC RC for an input of 150v and output of 61v can be shown as below.This shows the constant output volatge.

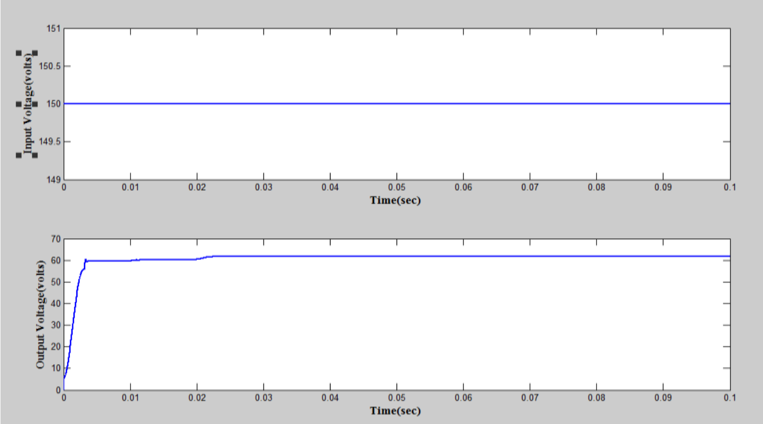

Fig.12.Input -Output plots of SPRC.

DC characteristics for LCC RC are displayed below.

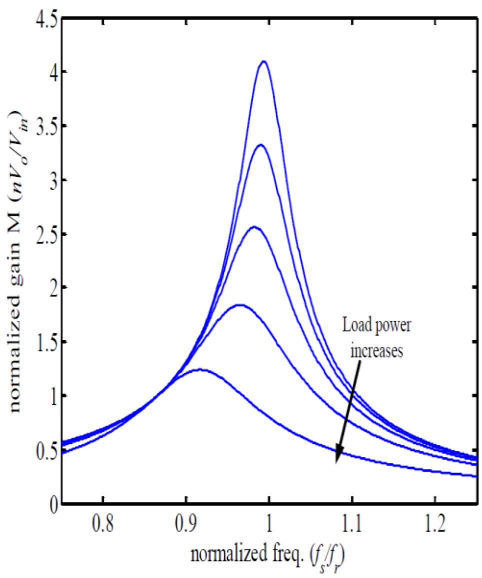

Fig.13.The DC characteristics for LCC RC .

LCC can handle zero load situation. Near light loads gain-frequency curve projects steep slope. circulating current is also limited.

LCC can never operate at above circuit resonant frequency, that is the highest efficacious point .The series part impedance in RC circuit is at its minimum magnitude with the inductance, capacitance canceled each other.

LLC Resonant Converter:

A transformer coupled dc/dc converter whose output is regulated by switching frequency is treated as LLC RC [1] . The terrific benefit with a LLC is that ZVS is performed at simple load also In backward operation mode ZVS is only possible at heavy load – like a traditional phase shifter , also it has the benefits like maximum efficiency, and also its compact size. Though it has several drawbacks like complicated synchronous rectification And Large switching frequency change when it works as bi-directional converter. An interleaved LLC-SRC with a simple controller is contemplated in [2]. The circuit of LLC RC is as shown below

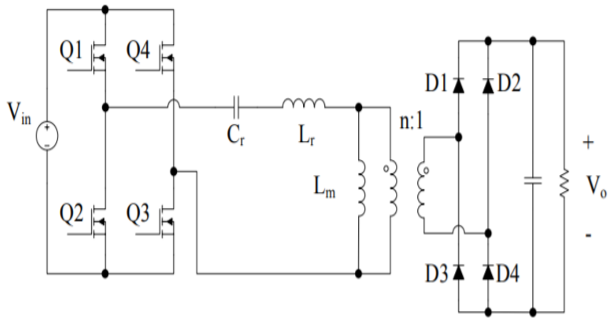

Fig.14.LLC Resonant Converter.

Simulink diagram for LLC RC is displayed below

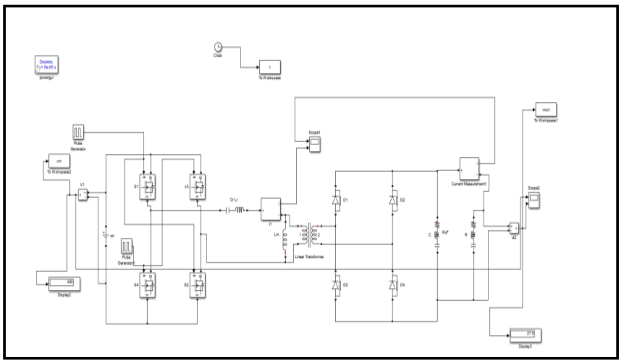

Fig.15.simulation circuit of LLC RC.

It is For a given high input of 150 v the output voltage of 12.5v is obtained as shown below.

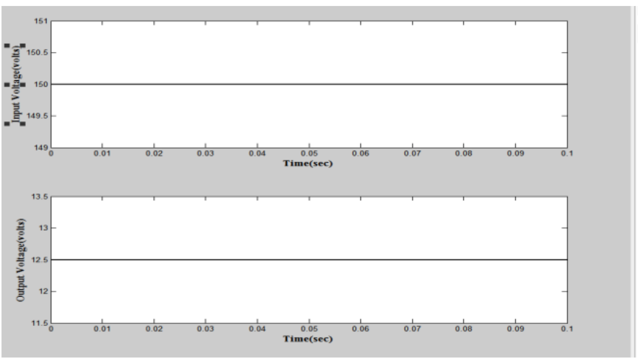

Fig .16.Input output plots of LLC RC.

DC characteristics for LLC RC can be below.

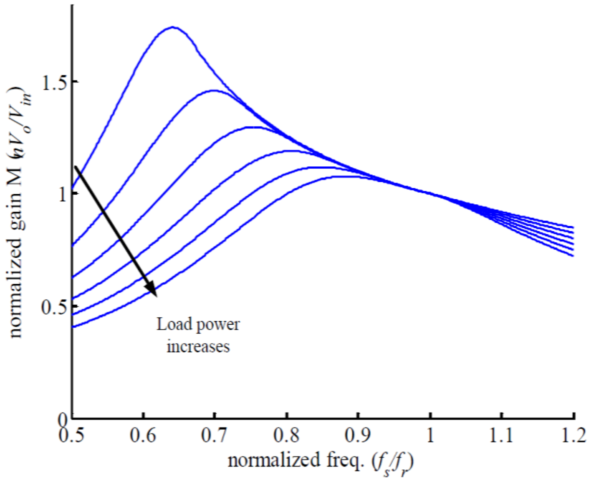

Fig .17.The DC characteristics for LLC resonant converter.

LLC converter have a load -independent peak gain , which makes ZVS possible with highest efficiency, which is not achieved in no resonant converter, and this projects LLC as peculiar among resonant converters.

Advantages of Series-Parallel resonant converter:

1) Step-down ,step-up characteristic.

2)Low-voltage high-current application.

3) Desirable for multiple outputs.

Disadvantages**:** These are uni- directional.

III APPLICATIONS

Series-Parallel RC is incorporated ,for Wastewater Treatment SPRC results High efficiency energy exchange system which is contact less. From the Late 1980's, LLC RCs have various applications. In [5,6] LLC RCs used in X-Ray Imaging. A development can be made from same is incorporated in [7] for X-Ray tube. Besides X-Ray Imaging, in [8], The author has used the converter to regulate Distortion in the X-ray Tube. In Biomedical area , the author from [9] has used the Converter for Sterilizing Microbes which will be a fruit full for researchers. With LLC RC high DC Voltage i.e. generated and provided to Renewable Energy in [10].In [11], the RC is regulated by PWM technique, used for Ozone Generator Application. In [12], Multiple stacks of RCs are framed to enhance voltage ,high power. Series Combination of LLC-LC RC can run Motors namely in [13], it has driven a PMDC Motor . Bidirectional LLC RCs that operates in forward ,backward modes with a good output power[14].

Other applications that include inherent properties of RCs with no feedback and good repeatability are as follows:

1) arc welding [15];
2) induction heating [16];
3) ozone generation [17];

IV CONCLUSION

The tabular form representing the different resonant topologies with their frequency with ripple content is displayed below.

TOPOLOGY	INPUT VOLTAGE	SWITCHING FREQUENCY	OUTPUT VOLTAGE	OUTPUT RIPPLE
SERIES	150	100khz	25.5	0.12
PARALLEL	150	100khz	251	0.1
LCC	150	100khz	61	0.2
LLC	150	100khz	12.5	0.01

From the study of various resonant converters along with their performance analysis we can ultimate that the LLC RC has the superior performance in means of high efficiency, high output regulation and buck/boost operation capability. hence apt in vehicular applications .A bidirectional converter may be enrooted to enhance performance in forward ,back ward modes. The efficiency parameter can be incorporated in the design of converters.

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