International Journal for Modern Trends in Science and Technology, 8(08): 14-21, 2022

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0808003
Available online at: http://www.ijmtst.com/vol8issue08.html

A Comprehensive Review on Enhanced Series Resonant Converters

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To Cite this Article
Shubham Subhas Borkar and Guruswamy K P. A Comprehensive Review on Enhanced Series Resonant Converters. International Journal for Modern Trends in Science and Technology 2022, 8(08), pp. 14-21. https://doi.org/10.46501/IJMTST0808003

Article Info
Received: 25 June 2022; Accepted: 30 July 2022; Published: 04 August 2022.

ABSTRACT

In a wide-output voltage range application, the resonant converter must achieve high efficiency and minimal switching frequency over a broad output voltage range. Many resonant topologies have been developed that satisfy these requirements. These topologies are listed in this study. This article surveys and compares DC-DC resonant converters for applications requiring a wide output voltage range.Series resonant dc-dc converters are an established technology that are typically utilised in situations that call for consistent dc voltage gain. The application just improved them enhance rectifiers. This method revealed freshchances to extend the range of input voltage control.Analysis of the LC series resonant DC-DC converter's operating mode, deduction of the switching-off conditions, and analysis of the converter's power transmission and soft switching properties under various switching-off scenarios

KEYWORDS: Resonant converter, Efficiency, Switching Frequency, Controller.

1. INTRODUCTION

Resonant converters have been widely discussed in the literature since they were first introduced decades ago. Switch soft-switching in resonant converters is made simple by operating in near resonant mode. Therefore, it is very important to operate resonant converters with the least amount of resonant tank current in order to lower conduction losses and improve overall efficiency. In the meantime, component stresses can also be decreased.

A DC/DC converter based on a resonant circuit that enables soft-switching operation is the Series Resonant converter (SRC). Switching happens in a soft-switching converter when voltage and/or current levels are zero, greatly increasing the converter's efficiency. When the voltage or current is zero while the switch changes states, it is said to have zero-voltage switching (ZVS) or zero-current switching (ZCS) [1].

SMPC's Series Resonant topology is one of them, for high voltage high power applications, converters (SRC) are preferred. The SRC's resonant tank successfully utilizes the high voltage transformer's huge parasitic leakage inductance. As soft switching may be accomplished, switching losses and stress can be reduced. Increased switching Consequently, frequencies are feasible, reducing the size of EMI generation is decreased by the converter. In terms of output, In the case of the SRC, a straightforward capacitor filter is sufficient; thus removing the need for an expensive and large high voltage filter inductors [1]. A converter with frequency control is the traditional SRC. To obtain the desired voltage gain, the switching frequency is changed in relation to the resonant frequency. The fluctuating switching frequency is a drawback.

2. SERIES RESONANT CONVERTER

2.1 Series Resonant Converter Operating in Discontinuous Conduction Mode

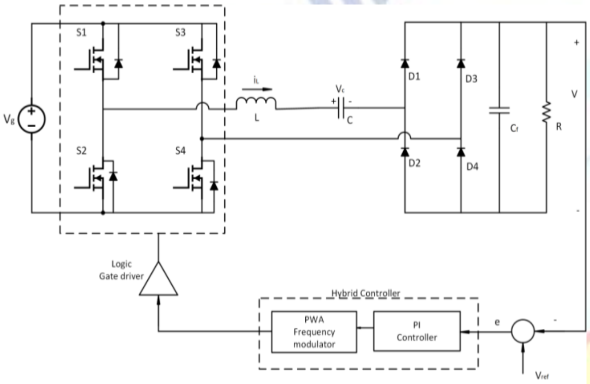

Fig 1: Schematic of the proposed hybrid control of the SRC

The switching algorithm for the SRC's switched linear dynamics depends on both discrete input and continuous state variables. Such hybrid systems stability analysis and control design are extremely challenging and complicated. With the difference that the switching rule solely depends on the continuous state variables, PWA systems are another family of hybrid systems that resemble switched linear systems. Some linear matrix inequalities can be used to simplify the stability analysis and control design of PWA systems (LMI).

Two steps make up the presentation of the suggested hybrid controller: To display a PWA dynamics in the overall system created by connecting the FM and the SRC, a novel frequency modulator is offered in the initial step. The second phase involves designing an output feedback controller based on the stability theorems of PWA systems in order to manage the converter's output voltage and ensure the stability of the closed-loop system [2].

2.2 Series Resonant Converters Using Average Geometric Control.

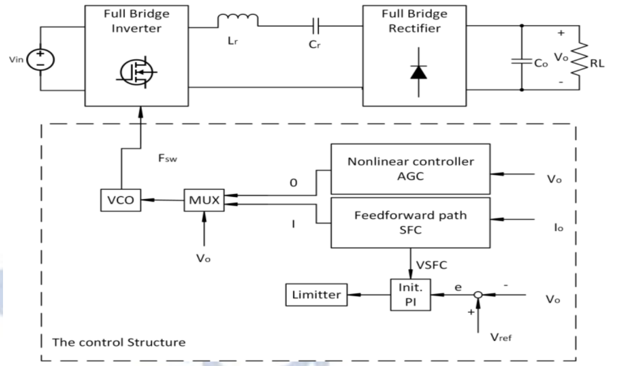

Fig 2 : Conceptual block diagram and sensing strategy for the control structure.

The suggested SRC's large-signal model, which will be used to create a controller with exceptional dynamic response and discover the SRC's typical circular paths. Any system, including a resistive load, can be linked to the SRC's output. However, in accordance with the fundamental ideas of electrical circuit theory, a step input is supplied to the circuit when all of the initial conditions are zero in order to produce the dynamic response of a linear circuit itself. The dynamic of the resonant tank is examined while the SRC is modeled and a nonlinear controller is suggested. The dynamic of the system may be slower since the outer voltage loop has a relatively long constant time, which mostly influences the converter's start-up reaction.

The performance of the converter needs to be step-by-step analytically delineated in order to compute the dynamic response of the SRC to the step-input. The converter must operate at its maximum and minimum gains while resolving transients in order to have the quickest response possible during start-up, load step-up and step-down, and reference voltage step-up and step-down [3].

2.3 Series resonant converter using a continuous current mode

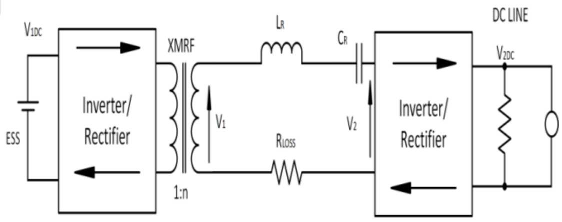

Fig 3: General bidirectional SRC DC/DC converter diagram.

Any converter with a bidirectional mode of operation must have at least one step-up mode of operation in the circuit.

However, the series resonant converter (SRC) is a step down converter and boosts voltage using a transformer. However, when the transformer turns the other way, the SRC and the transformer both lower the voltage, resulting in a final voltage that is lower than what is necessary.

Fig 3.provides a better explanation for this. Using the ports in Fig. 1 as a reference, the voltage conversion ratio (M) for any kind of bidirectional DC/DC converter. Many converters contain a transformer to enhance the output voltage and provide galvanic isolation, therefore M12 and M21 are dependent on the transformer turns ratio (n). In these circumstances, the definition of a normalised voltage conversion gain is $M_{21}=V_{2DC}/(n\ V_{1DC})$ and $M_{12}=n\ V_{1DC}/V_{2DC}$ when the transformer turns ratio's impact is negated. Consequently, a system with a transformer in it has a voltage conversion gain that is written as $M_{21}=m_{21}\cdot n$ and $M_{21}=\frac{m_{12}}{n}$ [4].

2.4 Series LC Resonance-Pulse Based ZCS Current-Fed Full-Bridge DC-DC Converter

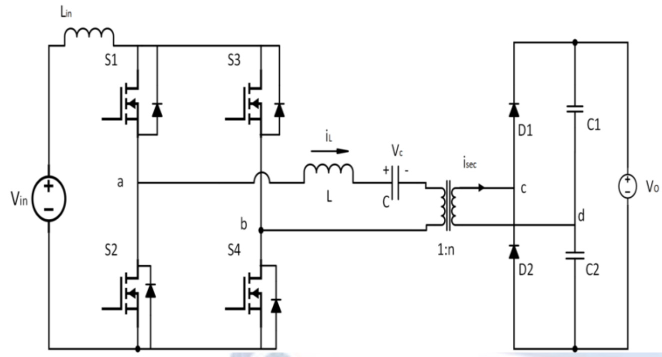

Fig 4: Proposed series-LC resonant-pulse current-fed full-bridge dc-dc converter with voltage doubler.

Fig 4.shows the suggested full-bridge voltage doubler circuit fed by a series resonance-pulse current. To achieve soft-switching, series resonance makes use of a series capacitor and the transformer leakage inductance. By using variable frequency control for a wide variety of source voltages for a constant load application, output voltage regulation is accomplished. Fixed duty cycles are designed so that they allow enough time to ensure soft-commutation under all operational circumstances. When compared to converters with extensive switching frequency variation, moderate frequency variation is observed across the whole range of the source voltage, allowing for relatively simple magnetic design and control implementation. Gate signals that are 180 degrees phase-shifted and have a slight overlap are modulated to drive switch pair S1, S4 and S2, S3. These presumptions are established for the simpler analysis [5].

a) To maintain minimal ripple current at the input, a boost inductor with a sufficiently large value is selected.

b) Each and every semiconductor device are ideal and lossless.

c) The output filter is big enough to keep the output voltage constant.

d) The HF transformer's high magnetising inductance value is taken into account.

2.5 Series Resonant Converter with Minimized Tank Current and Wide ZVS Range

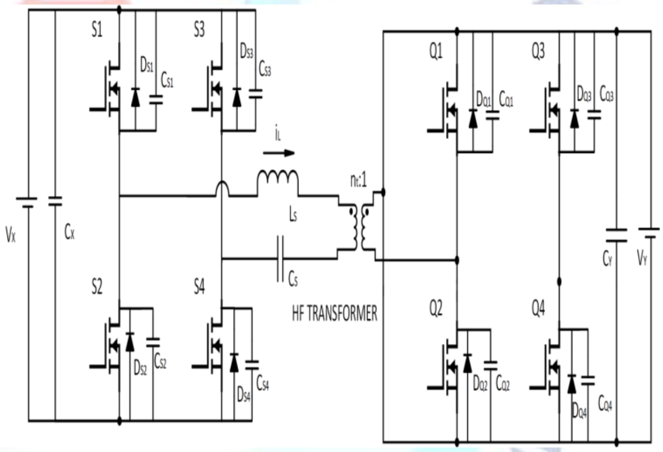

Fig 5: Circuit diagram of a dual-bridge series resonant converter.

Fig 5.depicts an HF-isolated dual-bridge series resonant converter. It has a virtually symmetric structure with two H-bridge circuits that are isolated from one another by an HF transformer and an LC-type resonant tank. Four power switches and their anti-parallel body diodes form each bridge. Snubber capacitors, also known as switch parasitic capacitors, are placed across the switches. The FHA technique can be employed for the steady state analysis of this resonant converter with tolerable accuracy due to the near resonance functioning. The following presumptions are utilised in the FHA analysis. It is believed that all switches and diodes are perfect. The HF transformer's magnetising inductance is believed to be unlimited. The HF transformer's leakage inductance can be viewed as a component of the resonant inductance. The best choice of three angles for manipulating power should be chosen because the average power is a result of three different factors. Since AAPWM has the capacity to maintain up to seven switches in ZVS under light load, the specified control route should be chosen to operate with the least amount of tank current possible in order to minimise conduction loss. Since it is the primary cause of conduction loss in switches, the rms tank current is chosen as the aim to be minimised in this work [6].

2.6 Series-ResonantDC/DC Converter Over WideRange of Battery Voltages

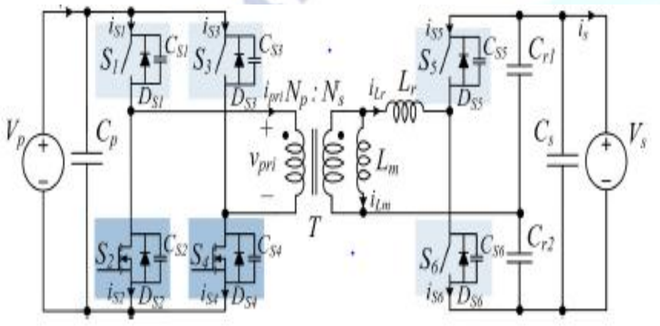

Fig. 6.Circuit diagram of the proposed converter.

The suggested converter functions as a half-bridge resonant boost converter when moving backward. Secondary side switches S5 and S6 work in a complimentary way with a constant duty ratio of 0.5 and little idle time. S4 is turned on immediately after setting S6 ON, whereas S2 is turned on with a variable duty ratio of 0.5 + Db soon after turning S5. S2 and S4 aid in the sinusoidal waveform's sinusoidal growth of iLr. The proposed converter can greatly enhance Vp in comparison to the standard converter and can therefore be employed when the voltage difference between Vp and Vs is quite large. In the first half-switching phase, the detailed analysis is presented for the following four modes.

2.7 Series-Resonant DC-DC Converters for Wide Load Variations

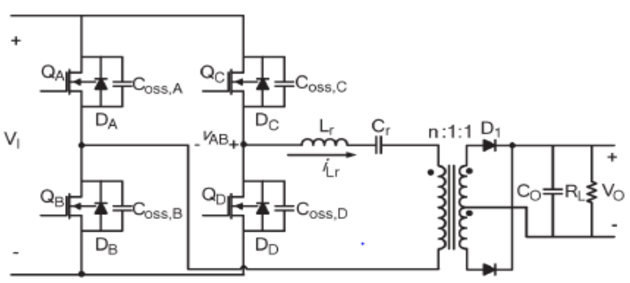

Fig. 7: Full-bridge SRC and the gate signals

The design of a phase-shifted full-bridge series resonant converter is presented in this study (PS-FB SRC). A new two-mode operation is a feature of the planned FB SRC. At normal loads, it is operated in series resonant mode. The output voltage is controlled by changing the switching frequency. On the other hand, the fixed-frequency phase-shifted pulse width modulation is employed to modify the output voltage and control the effective duty cycle for light loads. For a variety of load circumstances, the suggested converter demonstrates good conversion efficiency. It is described and evaluated how the voltage gain, switching frequency, and effective duty cycle are related. A 48-V/42-A prototype is then put into practise. In order to validate the theoretical analysis, experiments are carried out.

2.8 Series/Series-Parallel CompensatedContactless Resonant Converter

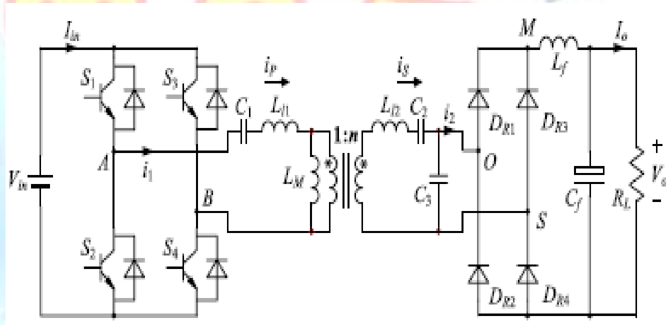

Fig. 8. S/SP compensated contactless resonant converter.

The series/series-parallel (S/SP) compensated contactless resonant converter has the advantageous property of being insensitive to changes in parameters, such as the coupling coefficient of the transformer. The basic harmonic approximation produces a sizable amount of error, complicating the design process and reducing the effectiveness of the control. This study presents a detailed features analysis of the S/SP converter. The S/SP resonant tank's generalised equivalent circuit is derived, and the reason of the waveform distortion is identified. Then, more precise equations for the output voltage gain and the main resonant tank parameters are provided. An S/SP compensation 1.5 kW contactless resonant converter is built in the end.The estimated results and the experimental results agree fairly well.

2.9 Quasi Current Mode Control for thePhase-Shifted Series Resonant Converter.

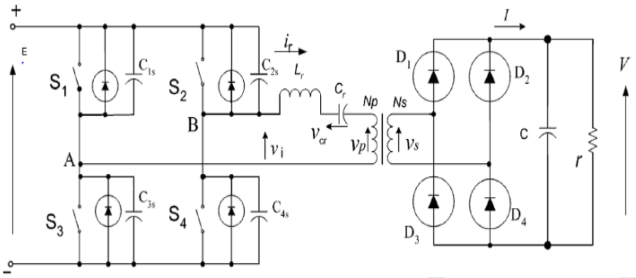

Fig 9: Fig. 1. Main circuit of the PSRC.

The phase-shifted series resonant converter system uses a unique indirect current mode control. The current is produced from the vector of the resonant tank, and the resonant current is indirectly controlled by quasi current mode control, improving the dynamic performance of the converter system. For the system, only one voltage feedback is necessary. The suggested system comprises of two control loops: an outside voltage loop and an inner resonant vector loop. Analysis and actual experiments are conducted, and the results demonstrate improved performance when compared to the traditional control.

2.10 Series Resonant DC-DC Converter With Wide-Input and Configurable-Output Voltages

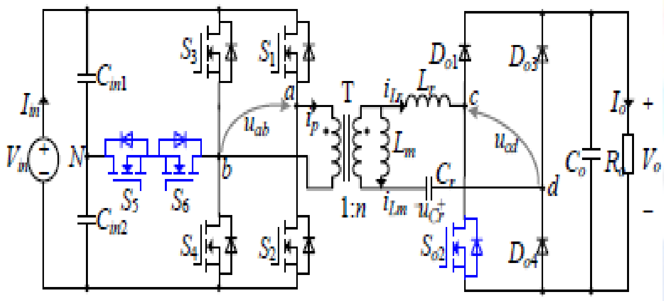

Fig. 10.Schematic of the proposed series resonant dc-dc converter.

The innovative series resonant DC-DC converter that is proposed in this research has four customizable operating states that vary with the input and output voltage levels. It works well with grid-connected photovoltaic (PV) systems at the DCDC stage that have a wide input voltage range and various grid voltage levels, such as 110/120 V and 220/230/240 V. On the primary side of the proposed converter is a dualbridge structure, and on the secondary side is a programmable half- or full-bridge rectifier. The primary-side MOSFETs and secondary-side diodes may achieve zero-voltage switching (ZVS) on and zero-current switching (ZCS) off, respectively. The root-mean-square (RMS) currents are kept low over a fourfold voltage-gain range. As a result, the converter may continue to operate at high efficiency levels over a wide voltage gain range.

The proposed converter's viability has been tested with a prototype.The suggested converter is given a fixed frequency pulse width modulated (PWM) control mechanism, increasing the gainqualities that are not depending on the magnetising inductance andThis makes the resonant tank's design optimization simpler.First, the topology and guiding principle of the converter are described.The properties, such as dc voltage gain and soft switching, are then discussed and RMS currents are described before comparing performance is carried out using traditional resonant topologies. Furthermore, also mentioned are the suggested converter's design specifications.The experimental outcomes from a 500-W converter are also presented.The proposed converter's viability has been tested with a prototype.

3. COMPARISON OF SERIES RESONANT CONVERTERS.

Table 1: Comparison Table for series resonant converter (SRC).

Paper	Controller	Efficiency	No. of Diodes	No. of Switches	Applications	Source	Software	Advantages	Disadvantages
[1]	Hybrid Controller	Higher	8	12	Industrial magnetron, renewable energy, LED driver.	DC supply	Matlab	Higher power density, lower electromagnetic interference.	Complex circuit and high cost.
[2]	Linear PI Controller	---	4	8	power factor corrector	DC supply	PSIM	prevent voltage overshoot	large transients

					systems			following disturbances	
[3]	PI controller	Higher	8	8	bidirectional power flow applications	DC supply	Matlab	greater efficiency for light loads	Switching frequency is not constant
[4]	---	95.6%	6	10	battery charging and constant power motor drive	DC supply	Matlab	the switches are soft commutated	high component count, increased cost and complexity
[5]	volatge/current stabilization controller	96.15%	8	16	high-voltage low-current applications	DC supply	PSIM	high power density, high efficiency and soft switching	high circulation current at light load
[6]	PI controller	96%	6	10	3 – phase inverter	DC supply	Matlab	Stable fixed frequency.	Error amplifier compensation
[7]	Fuzzy logic controller	97%	4	6	Used in both resistive and battery loads	DC supply	PSIM	Fast tracking, less complexity	Drift problem occurs.
[8]	Sliding mode control	---	8	8	satellite systems.	DC supply	PSIM	Better voltage regulation.	No limits on control cost
[9]	Voltage mode control	---	6	10	Low power application	DC supply	Matlab	High dynamic and static efficiencies	Required loop compensation
[10]	PI controller	Higher	8	12	Fuel cell stack, battery	DC supply	PSIM	High voltage gain	Increased complexity

4. CONCLUSION

This paper presented a review and comparison of different resonant converters. Series resonant converter demonstrates that the key benefit is that it exhibits excellent efficiency for large power transfer and greater efficiency for light loads. Conceptualization and research are done on a full-bridge, current-fed partial resonance, series resonant tank dc/dc converter.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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