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A CONTROL SCHEME SERIES RESONANCE DC-DC CONVERTER

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ABSTRACT- The development of power conversion technology is in constant demand in order to get high power efficiency and high power density. The DC-DC power conversion is necessary for many power supplies and power related applications. In Solid State Transformer (SST), renewable energy systems or even in telecommunication applications the continuous system operation is necessary. For this the highly reliable system is also required. Series resonance DC-DC converter (SRC) became most popular in solid state transformers. The SRC has been frequently used in electrical vehicle, renewable energy systems for wireless power transfer. To achieve soft switching and low EMI the resonant DC-DC converters are used. This paper proposes a reconfiguration method in SRC in case of one semiconductor failure, which reduces the need of discharge drastically. In this proposed method, the SRC based full-bridge is reconfigured to a half-bridge topology, to keep the converter operational even one switch failed. The full- bridge SRC is double the voltage of the half bridge. To maintain the constant output voltage after the fault HB-topology along with voltage doubler is used on the secondary side. For reducing the Total Harmonic Distortion PI controller is used. This mode of operation is an accurate model; an MATLAB/ SIMULINK model is designed and built to exhibits its accuracy in operation waveforms and gain prediction.

I. INTRODUCTION

The techniques for conversion of power are processing and transferring electric power; power converters are needed all over the place in this era of electricity. The power conversion is an main link to supply the power to the end-user electronic devices or the power transmission or storage applications. From the field of generating renewable energy to the supply of power to a portable digital device, all the fast advancement in this technology imposes intense challenges in the power electronics. From the past several decades, achieving high efficiency of power and high density of power is constantly demanded by the development of electricity transmission, generation and power supply technologies, and has become the focus of the power conversion. A common description of each circuit, advantages and disadvantages are explained here. The difference between each topology is found in the resonant tank. Figure 1 shows a rectifier block, switching network and resonant tank.

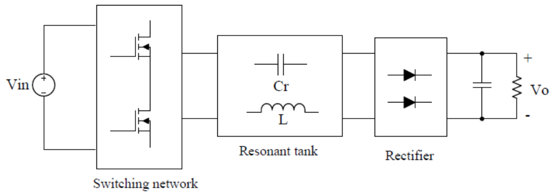

Fig:1. The general scheme of a DC-DC resonant converter

Main advantages and disadvantages of series resonant converter are presented here:

1) Series resonant converter is suitable for high power applications in full bridge because the series resonant capacitors act as a DC blocking capacitor on the primary side.
2) The main disadvantage in series resonant converter is no output-voltage for no load case. Only applications with no load regulation are required for this converter.
3) For applications with low output-voltage and high current is a disadvantage to have an output DC filter flowing high ripple current. High output-voltage and low output current applications are more appropriate for these converters than low output voltage and high output-current converters which are not suitable.
.4) High load efficiency is conserved because the current in the power devices decrease as the load decreases. It lets the power device conduction losses to be reduces as the load decreases.

In the system, there are two types of failures in the semiconductor: short circuit (SC) and open circuit (OC). The causes of an OC failure are rupture or bond-wire lift off and gate drive failure. The SC failure causes due to an overvoltage, dynamic or static latch up, breakdown, or power shock. As many failures result in an Short circuit condition, this paper mainly focus on SC failure. The proposed configuration method consists of reconfiguring the full-bridge SRC (FB-SRC) to a half-bridge SRC (HBSRC). However, the generated output voltage in HB-SRC is half of the generated output voltage by the FB-SRC, by considering the same limits. Therefore, to maintain the constant voltage output a voltage-doubler

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topology is proposed based on a novel reconfigurable rectifier.

In process of power conversion resonant DC-DC converters are the converters that consist of L-C resonant tank as a main part. The basic concept of the resonant converter is, the circulating power in an L-C resonant circuit is controlled by changing the operating frequency, to get the desired output voltage. In general, a resonant converter consists of a rectifier, resonant tank, and a switch network as seen in Figure 1. The switch network which could be full-bridge or half-bridge configuration is used for the generation of a square voltage excitation. The resonant tank is used for flowing and delivering the energy, which exhibits sinusoidal voltage and current waveform during the intervals of a switching cycle. Unlike the PWM converters, the resonant frequency of the L-C network is usually similar to the switching frequency, so the voltage or current variation during each cycle has much larger amplitude than the low-frequency ripple of the PWM converter. The resonant tank is widely used in DC/AC inverter to filter out the undesired high order harmonic components of the square-wave input to generate pure sinusoidal AC output, in which the system is similar to the resonant converter without the rectifier. In an inverter, the resonant tank acts like a frequency selector, whereas for converter the transparency of the sinusoidal waveform is not a concern as the rectifier and the output low-pass filter will convert the AC to DC. The different characteristics of the resonant converters are determined by the various resonant behaviors of an L-C tank.

The most important benefit of the resonant converter is the ability of achieving zero current switching (ZCS) and voltage switching (ZVS), which indicates the voltage or current of the converter switches crosses zero respectively during the switching transitions. Such mechanisms can help the converter to get rid of some switching losses, which occur when the switches turn on or off. Comparing to PWM converters like buck, boost or buck-boost, the resonant converter can operate in a higher switching frequency without the switching losses. Also, the periodic energy commutation via the resonant L-C elements become more frequent with the raise of operating frequency, and the required inductance or capacitance can be lower and hence the size of these passive components can be reduced so that the power density is improved. Another benefit from the soft-switching nature of the resonant topology is that the “noise” generated by the converter components can be minimized with the smooth switching transitions, and low electromagnetic interference (EMI) can be achieved.

II. OPERATION PRINCIPLE OF THE SRC

The FB topology based on SRC configuration is shown in Fig. 2(a). To simplify the explanation, an unidirectional topology is considered and a rectifier based diode bridge is used in the secondary side.

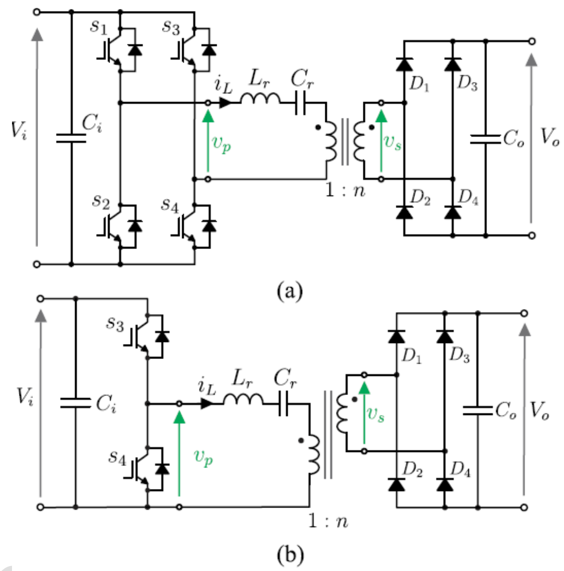

Fig:2. Series Resonant dc–dc converter: (a) topology of the FB-SRC, (b) topology of the HB-SRC.

The current iLr reaches zero prior to half of the switching period, when the operation is below the resonant frequency it remains zero until the negative output voltage is applied to the primary bridge, i.e., vp = −Vi . Since the commutations take place when iLr = 0, all semiconductors switch to zero-current switching, thus, avoiding switching losses. The operation mode of half-cycle DCM, is very beneficial because of the soft switching feature and considered for the analysis in this paper. Further the SRC can also be implemented based on the HB topology, as shown in Fig. 2(b). This circuit is recognized in the literature as LLC converter, by considering the magnetizing inductance of the transformer in the tank circuit, and it has been broadly used in telecommunications and power related applications. The operation of the half bridge converter is related to the one of the FB-SRC converter, as described previously. The difference between HB and FB converters lies on the resonant capacitor voltage [which has an offset of Vo in the HB-SRC converter, as shown in and also on the peak-to-peak value of the voltage vp. As mentioned earlier, the two possible failures: OC or SC depends on the semiconductor failure. In case of voltage source converter, the open circuit fault is not catastrophic, since the power transfer is interrupted naturally. Due to short circuit fault is there is a destructive damage to the power converter. In addition, the SC failure type is likely to happen more in the real application than the open circuit failure. Therefore, the reconfiguration method proposed in this paper is analyzed for the SC fault case, although it can also be used for the OC fault.

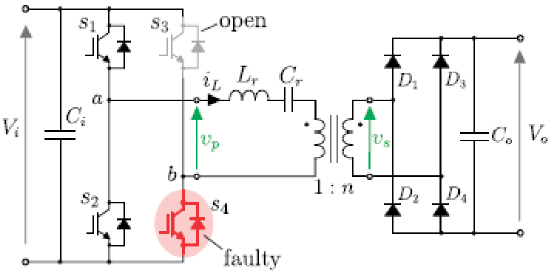

Fig:3. FB-SRC under fault condition: SC failure on the semiconductor S4.

The proposed configuration method for the SRC is reconfiguring the FB-SRC to an HB-SRC when fault occurs, i.e., short circuit of a semiconductor. The complete analysis is carried out in this section for the FB-SRC as shown in Fig. 3. For example, assume that switch S4 is damaged in short circuit (see Fig. 3); therefore, switch S3 must remain open, to avoid the short circuit of voltage source at input side. As switch S4 is short-circuited, the point b (highlighted in Fig. 3) is directly connected to the ground on primary side and the damaged switch is used as a circuit path, resulting in the same circuit of the Fig. 2(b). In the meantime, the healthy leg (composed of S1 and S2) operates normally. As the voltage output of the HB-SRC is half compare to the FB-SRC, when fault occurs the voltage output of the converter is also half of the original value, which is not preferred. Therefore, to nullify this problem and maintain the constant output voltage after the fault, the secondary side of the circuit has been modified and a novel configurable rectifier is obtained.

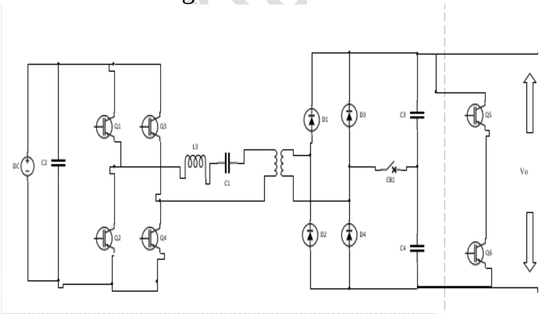

Fig:4. Proposed SRC based fault-tolerant topology.

Finally, Fig.4 shows the complete proposed SRC based fault-tolerant (FT-SRC). A fault diagnosis and detection method must be used to detect the fault and identify the faulty semiconductor. The main purpose of this is to suggest the reconfiguration method for the SRC converter and to propose the FT-SRC, as mentioned earlier. Therefore, the existing methods are used to determine the failure in the converter. It is known that the IGBT devices can withstand irregular current only a short period of time, usually around 10 µs, which is significantly large. Among the different methods that are implemented to this converter, de-saturation detection method, gate voltage limiting protection, current mirror method, and sensing of gate voltage are much promised. All these methods require the sensing of device collector current or/and voltage and, thus, they are significantly very simple to implement.

III. SIMULATION RESULTS

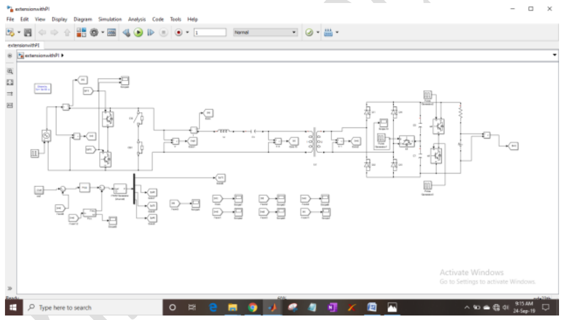

Fig:5. Topology of Half bridge with PI controller

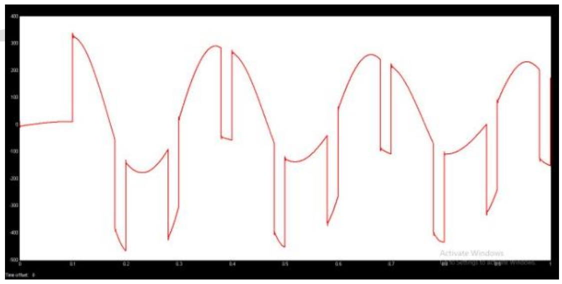

Fig:6. waveform of Voltage (Vc) on the primary side

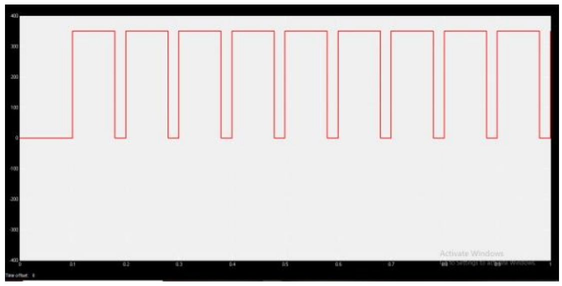

Fig:7. Voltage (Vp) waveform across half bridge topology

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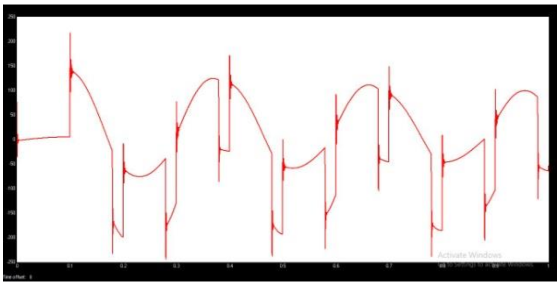

Fig:8. Voltage (Vs) waveform on the secondary side

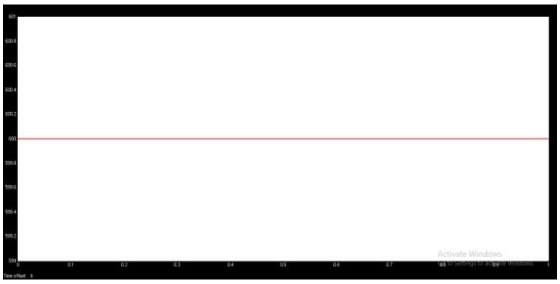

Fig:9. Output Voltage (Vo) waveform

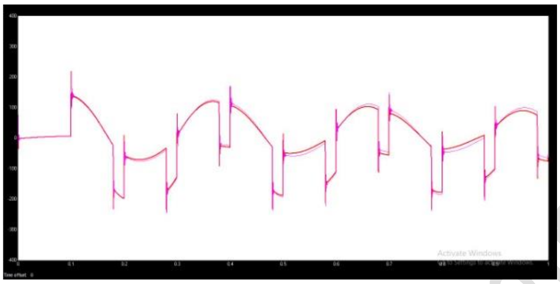

Fig:10. Waveforms of Voltage (Vs) with and without controller

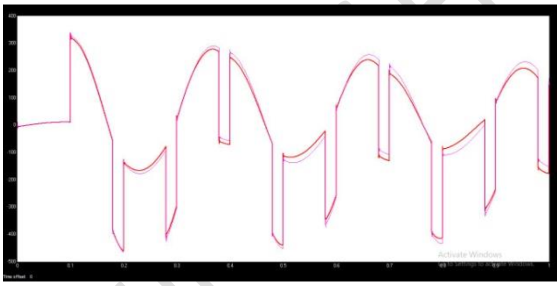

Fig:11. Voltage (V) waveforms with and without controller

IV. CONCLUSION

This paper proposed an SRC based FT. The basic operations of the SRC based FB and HB topologies were described. Then, a Short circuit fault case is implemented for the FB-SRC and a reconfiguration method, in which the FB-SRC configures as an HB-SRC, is presented. As a result of this method, the output voltage becomes half. To overcome this problem a voltage-doubler rectifier along with PI controller is used to maintain the output voltage constant. The main advantages of this converter are post fault operation, simple implementation, reduced number of additional components, and no efficiency deterioration. However, the resonant capacitor must be intended for high current and voltage effort on the healthy devices in failure mode operation is twice than that of normal mode operation. Simulation results were obtained and the advantages and efficiency of the proposed SRC based fault-tolerant has been verified.

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