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INVESTIGATION OF LCL RESONANT CONVERTER

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Abstract—The resonant converter is widely used in the areas of space, radar power supplies, telecommunication and aerospace. The reason for using resonant converter instead of DC–DC converter is there may be losses. The output of DC–DC converter is always lesser than the input. In this paper the concepts of fuzzy and RTOS (Real Time Operating System) are used. The fuzzy controller is used to increase the performance and the RTOS is used to increase the stability. The existing RCs are LCC, LCL, and LCL-T topologies are used broadly. Comparing to these three configurations the LCL RC has the good stability region. To prove that the LCL RC has the good stability region the comparison between the three topologies and LCL RC are done in this paper. PI controller are also used to increase the performance. But, the process for the PI controller calculation is too difficult. We cannot able to understand or express the concept clearly. And the main disadvantage in using the PI controller is, the stability region of PI controller is not good compared to the fuzzy controller. So, the comparison between the PI controller and Fuzzy controller also made in this paper. To implement the controller for an RC the advanced RISC machine processor LPC 2148 is investigated.

Keywords- stability and performance analysis, DC-DC power converters, fuzzy controller,PI (proportional integral) controller,resonant power converters, RISC processor.

1.INTRODUCTION

The development of various dc-dc resonant power converters (RCs) leads to the telecommunication and aerospace applications. But these converters experience electromagnetic interference (EMI), high switching losses, acoustic noise at high frequencies, reduced reliability. The series and the parallel resonant converters are the two basic RC topologies. These two topologies have both advantages and disadvantages. The advantages of SRC include better load efficiency due to the series capacitor in the resonant network and the inherent dc blocking capability of the isolation transformer. The disadvantages of SRC are load regulation is poor and output-voltage regulation at no load is not possible by switching frequency variations. The advantages of PRC are better no-load regulation. The disadvantages of PRC are poor load efficiency, lack of dc blocking for the isolation transformer. So, an RC with three reactive components is suggested for the better regulation.

2.REVIEW

Borage [1] have demonstrated the performance analysis of LCL-T resonant converter with fuzzy and PID controller using state plane analysis. This paper presents the simulation of closed loop series parallel resonant converter with LCL-T configuration. The fuzzy and PID controller has been used for closed loop operation. The state space approach has been developed by mathematical model and simulated. The performance of the converter has been increased by fuzzy controller. The Harmonic Spectrum and steady state error for the load condition have been obtained to calculate the work of controllers. The proposed system provides the better voltage regulation for dynamic load conditions.

Tiwari, and Kotaiah [2] have demonstrated the LCL-T resonant converter which behaves as a constant-current (CC) source operated with the resonant frequency. The output voltage increases linearly in a constant-current source with the load resistance. The practical application of open-load condition in a CC power supply, is an arc welding power supply.

Borage, Tiwari, and Kotaiah [3] have proposes the high-frequency half-bridge resonant converter. The application of high-frequency half-bridge resonant converter provides the capacitor charging-power supply (CCPS).

Borage, Nagesh, Bhatia, and Tiwari [4] have demonstrated the, Design of LCL-T resonant converter including the effect of transformer winding capacitance. This paper presents the severe degradation of output current regulation of an LCL-T RC due to transformer winding capacitance.

Maftaveli, Rossetto, Spiazzi, and Tenti [5] have demonstrated the, General-purpose fuzzy controller for DC-DC converters. In this paper, a general-purpose fuzzy controller for DC-DC converters is investigated based on a

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qualitative calculation of the system to be controlled by the fuzzy controller. It is capable of giving good performances even for those systems where controlled linearly.

Sivakumaran, Natarajan [6] presents the, Development of fuzzy control of series-parallel loaded resonant converter – simulation and experimental evaluation. This paper presents the development of fuzzy control algorithms in order to control the on-line overhead product. Composition of a batch distillation column is the influence of design parameters was evaluated through the simulations. The algorithms were experimentally tested by monitoring a pilot column. Binary mixtures of n-hexane and n-heptane were distilled by the temperature measurements and vapor-liquid equilibrium data. This is the basis for the inference of overhead and bottom compositions. There are two different operational strategies were used for the experiment. Constant overhead product composition and set-point trajectory increases the performance of fuzzy controller. The calculation for this method needs less time.

Borage, Nagesh, Bhatia, Tiwari [7] have demonstrated the characteristics and design of an asymmetrical duty-cycle-controlled LCL-T resonant converter. This paper explains the four operating modes which has the different switching circuits by the state space model.

Feng, Lee, Mattavelli, and Huang [9] have demonstrated the concept of a universal adaptive driving scheme for synchronous rectification in LLC resonant converters. This paper presents more intelligent and precise SR control by improving its efficiency.

Kang, Jung, Choi [11] explains the, Efficiency optimization in digitally controlled flyback DC-DC converters over wide ranges of operating conditions. This paper presents an approach to optimize the efficiency in digitally controlled flyback dc-dc converters over wide ranges of operating conditions. Efficiency is optimized by the power loss modeling, multivariable nonlinear constrained optimization power-stage and controller parameters. In the discontinuous conduction mode switching technique is adopted to reduce MOSFET turn-on switching loss. An optimization technique is formulated to minimize the power loss. A lookup table is used to achieve the on-line efficiency by programming switching frequencies and operating modes based on the efficiency optimization processes.

Park, Jung, Choi [12] have demonstrated Nonisolated ZVZCS resonant PWM DC-DC converter for high step-up and high power applications. The paper gives the nonisolated high step-up dc-dc converters. The applications are dc backup energy systems for UPS, photovoltaic and fuel cell systems, and hybrid electric vehicles. Nonisolated step-up dc-dc converter is improved by switching method shows the zero-voltage switching in continuous conduction mode. Switching losses is reduced.

3. PROPOSED SYSTEM

The *LCL* RC is designed to have fast response, better voltage regulation, and improved load independent operation. The *LCL* RC has been modeled and analyzed for various responses. The closed-loop models have been simulated using MATLAB/Simulink for comparing the performance with existing control techniques. Study of various literature works reveals that a microcontroller is being used to develop the two inverts required for driving the switches of the two legs of the single phase inverter. In a closed-loop system, an ADC is required to monitor at least any one of the system parameters—usually the terminal voltage on the output dc side. Hence, with a single microcontroller it is impossible to carry out the two jobs of monitoring and controlling independently.

Advent of the advanced RISC microprocessors, we can do many tasks in parallel. The operating system (RTOS) loaded onto the aforementioned processor to makes it possible to carry out multiple tasks. RTOS stands for real-time operating system. It overcomes, to a certain extent, the drawback of the Von Newman architecture that uses the fetch–decode–execute sequence. With RTOS a number of tasks can be carried out in a "near" simultaneous manner. The processor LPC 2148 has two sets of ADCs: ADC 0 and ADC 1. ADC 0 can handle eight channels while ADC 1 can handle six channels. All these channels can work independently. Typically, a multiple-input multiple-output (MIMO) system can, therefore, be controlled by LPC2148. With LPC 2148, the gap between the MIMO system design and implementation is reduced.

3.1. Block diagram of an LCL RC:

The block diagram of an *LCL* RC is shown in Fig. 1. The conventional RC that has two elements, the proposed resonant tank has three reactive energy storage elements (*LCL*). The first stage converts a dc voltage to a high-frequency ac voltage.

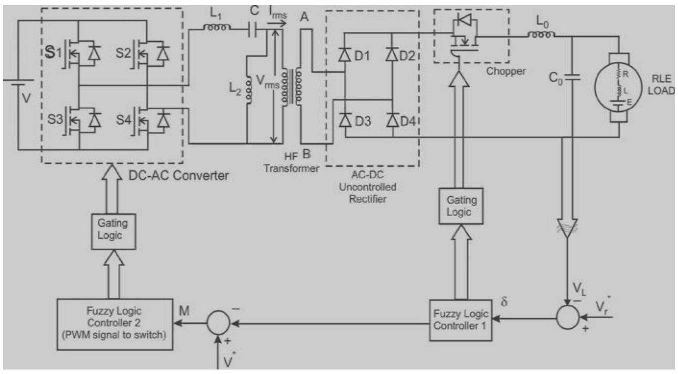

Fig: 3.1. Block diagram of the proposed LCL RC.

The second stage converts the ac power to dc power by a suitable high-frequency rectifier. Power from the resonant circuit is taken either through a transformer in series with the resonant circuit or in parallel with the capacitor comprising the resonant circuit. In both cases, the high-frequency feature of the link allows the use of a high-frequency transformer to provide voltage transformation and ohmic isolation between the dc source and the load.

In an *LCL* RC, the load voltage can be controlled by varying the switching frequency or by varying the phase difference between the inverters. The phase-domain control scheme is suitable for a wide variation of load condition because the output voltage is independent of load. The absence of dc current in the primary side of the transformer does not necessitate the requirement of current balancing. The advantage of this circuit is that the device currents are proportional to load current. This increases the efficiency of the converter at light loads because there is the reduction in device losses.

3.2. Equivalent circuit model of the LCL RC:

The resonant equivalent circuit consists of a series inductance $L1$, a parallel capacitor C, and a series inductance $L2$. S1–S4 are switching devices having base/gate turn-on and turn-off capabilities. The gate pulses for S1 and S4 are in phase but are at 180◦ out of phase with respect to the gate pulses for S2 and S3. The positive portion of the current flows through the MOSFET switch and the negative portion flows through the antiparallel diode. The load, resistive or inductive or capacitive or RLE, is connected across bridge rectifier via chopper, $L0$ and $C0$. The voltage across the point AB is rectified and fed to a chopper circuit. Load is connected through $L0$ and $C0$. In the analysis that follows, it is assumed that the converter operates in the continuous conduction mode and the semiconductors have ideal characteristics.

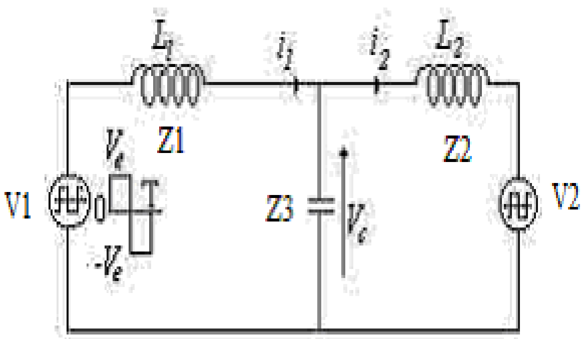

Fig: 3.2. Equivalent Circuit

3.3. State Space Analysis:

The following assumptions are made by the state space analysis:

1) Ideal switches, diodes, inductors used are used;

2) The snubber capacitors effects are neglected;

3) The losses in the circuit are neglected;

4) DC supply used is assumed to be smooth;

5) The waveforms are obtained from the fundamental components;

6) High-frequency transformer with turns ratio $n = 1$;

7) The state equation describes the state during the period $tp-1 < t < tp$ where $tp-1$ is the starting instant of continuous conduction mode and tp is the instant when the continuous conduction mode ends.

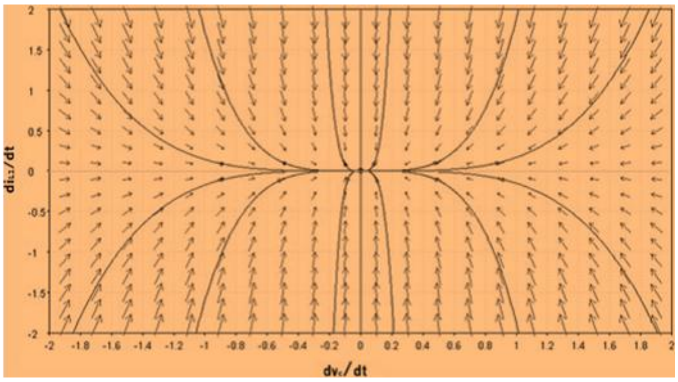

Fig: 3.3. State Space analysis of the LCL RC.

Phase plane (state plane) analysis is one of the most important techniques for studying the behavior of nonlinear systems, since there is usually no analytical solution for a nonlinear system. A phase-plane plot for a two-state variable system consists of curves of one state variable versus the other state variable ($x1$ (t) versus $x2$ (t)), where each curve is based on a different initial condition.

4. SIMULINK MODEL

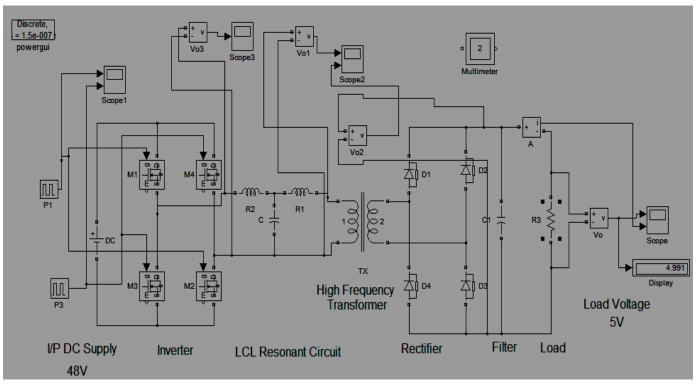

Fig: 4. Simulink model of LCL RC

Simulation in LCL RC takes place by three steps. From the membership functions of input 1, the lingual under whose range the actual values is present is found. Also, its decimal height degree of belief (DOB) is obtained. From the membership functions of input 2, the corresponding lingual is also found along with the DOB. For these two inputs, the output is fetched from the rule
matrix.

4.1. Result

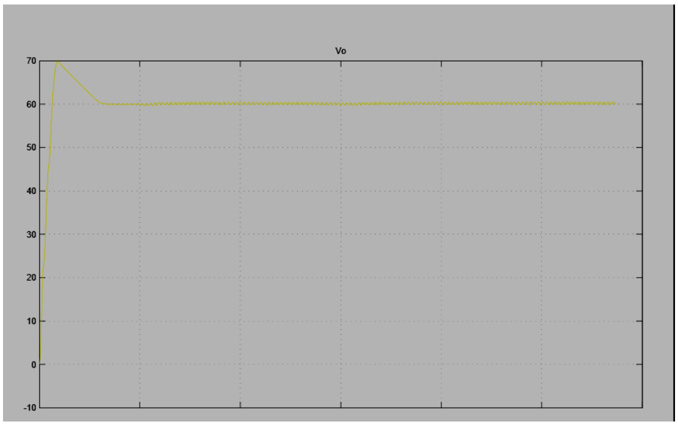

Fig: 4.1. simulated output

5. CONCLUSION

The *LCL* RC has a better stability margin compared to other three converters after a detailed stability studies using root locus, Nyquist, and state plane analysis. Fuzzy controlled closed-loop control system stability was also analyzed . FLC-based and PI-based *LCL* RC circuits were simulated using MATLAB/Simulink and also experimentally verified by implementing the ARM processor. The FLC provides better voltage regulation even under variation of load. The reduction in switching power losses improves the efficiency. The *LCL* RC can be used for applications such as space and radar. ARM processor LPC 2148 has been introduced as the controller for Fuzzy-based RCs.

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