Advances in Robotics & Automation

Anipireddy and Babu, Adv Robot Autom 2013, 3:2
DOI: 10.4172/2168-9695.1000120

Research Article Open Access

Modeling and Simulation of Three Level Piezoelectric Transformer Converters

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Abstract

This paper proposes a modeling and simulation of three level piezoelectric transformer converters. The increasing utilization of piezoelectric transformers (PT) in power electronics requires fundamental analysis and design of PT power converters. In addition, the possibility of overcoming the essential limitations of PT power ability by a combined operation of PTs needs to be examined. These studies could provide wide opportunities for PT exploitation in power electronic circuits.

The electrical circuit and model of piezoelectric transformers (PTs) ELS-60 is developed. Rosen-type PT and many other non-isolated conversion circuits have the inherit problem of the common neutral between the input and output that make it difficult to connect the output in series like the magnetic transformer. A new method based on the bootstrap method is proposed to solve the aforementioned problem. A new circuit for output summation of voltage level in the output side of each PT is developed. The impact of load and output filter capacitor on the conversion ratio and resonant frequency is discussed. The paper finally proposes a multilevel concept for many PT connected together for voltage summation. The method proposed can be applied to other multiple conversion circuits, which are based on common neutral between the input and output. The MATLAB/SIMULINK software used to design the required circuit diagram.

Keywords: Boost strap method; Converters; Piezoelectricity; Piezoelectric transformer; Rosen type PT

Introduction

Power electronic circuits have traditionally been based on magnetic technology, and until recently, have not been part of the tide of miniaturization and integration advances from which signal-processing integrated circuits have benefited [1]. The transformers and inductors in conventional converters are usually bulky compared to other elements. In an effort to miniaturize power components a piezoelectric, rather than a magnetic transformer could be employed in the power supplies [2]. Utilization of piezoelectric transformers in power electronics became possible owing to new piezoelectric materials that have recently been developed. These materials exhibit improved piezoelectric ceramic characteristics. In the past few decades piezoelectric transformers used widely in many applications, such as DC/DC converters, adapters, and electronic ballasts for fluorescent lamps [3].

Piezoelectric transformers (PTs) are electrical energy transmission devices that combine piezoelectric actuators as the primary side, with piezoelectric transducers as the secondary side. It transforms electrical energy into mechanical energy and back into electrical energy, i.e., unlike a conventional magnetic core transformer in which the magnetic field coupling is used between the primary and secondary windings [4]. Many PTs have been proposed and developed since the first PT was invented by Rosen in 1956, and it has been widely used and rapid developed, as compared with the traditional electromagnetic transformers. PT has big step-up ratio with small size, simple structure, lightweight, high conversion efficiency, good output waveform, no electromagnetic interference, etc [5]. Therefore, the convertors based on PT are very suitable for applications, which need high voltage source but low power. Currently there are three major types of PTs: Rosen, thickness vibration mode, and radial vibration mode [6]. This paper focuses on Rosen-type PT convertor and will use the single-layer Rosen-type model ELS-60 as an example. The model of ELS-60 with approximate parameters will be built in this paper. Because of the good performance of PT such that it can output perfect sine waveform even with square wave input [7].

Modeling of Equivalent Circuits

A PT can be modeled by an equivalent circuit like the one shown in Figure 1. C_{in} is the primary capacitance and C_o is the output capacitance. Some basic electrical specification of ESL- 60 PT is provided by the manufacturer. But other detailed parameters, such as R_m, L_m, C_m, have not been included, which shall be measured prior to any further researches [8]. By using an HP-4194A impedance gain phase analyzer, the electromechanical resonance modes can be measured from the impedance and phase versus frequency spectra.

It is well known that the parameters of PT depend on the load variations, temperature changes, components tolerances, etc. The equivalent circuit for typical DC-DC convertor based on PT for both voltage and current inputs are shown in Figure 2 and 3 [9].

When the output terminal of PT is shortened, its equivalent circuit is shown in Figure 4(a). When the input terminal of PT is shortened, its equivalent circuit is shown in Figure 4(b). Therefore, the parameters of the PT model measured by short-circuit test just are approximate values [10]. In order to obtain the maximum power output or stable

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Received May 12, 2014; **Accepted** May 31, 2014; **Published** June 2, 2014

Citation: Anipireddy P, Babu C (2014) Modeling and Simulation of Three Level Piezoelectric Transformer Converters. Adv Robot Autom 3: 120. doi: 10.4172/2168-9695.1000120

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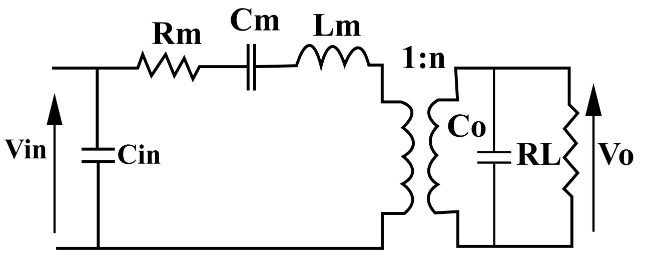

Figure 1: Equivalent circuit PT model

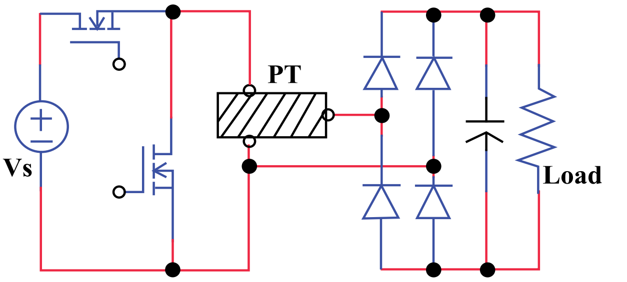

Figure 2: Equivalent circuit for typical DC-DC convertor based on PT: Voltage input

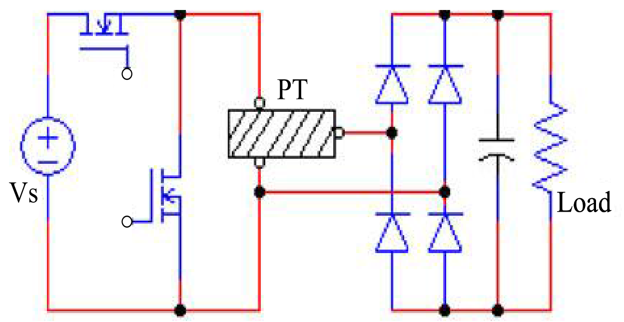

Figure 3: Equivalent circuit for typical DC-DC convertor based on PT: Current input

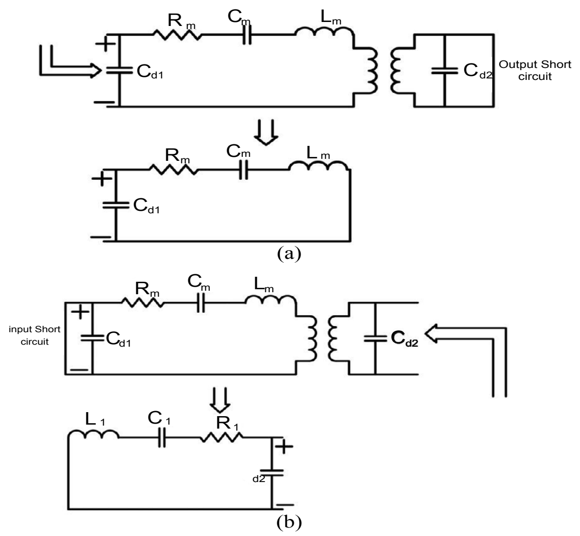

Figure 4: Equivalent circuit model of PT when output shorted and input shorted. (a) Output shorted. (b) Input shorted.

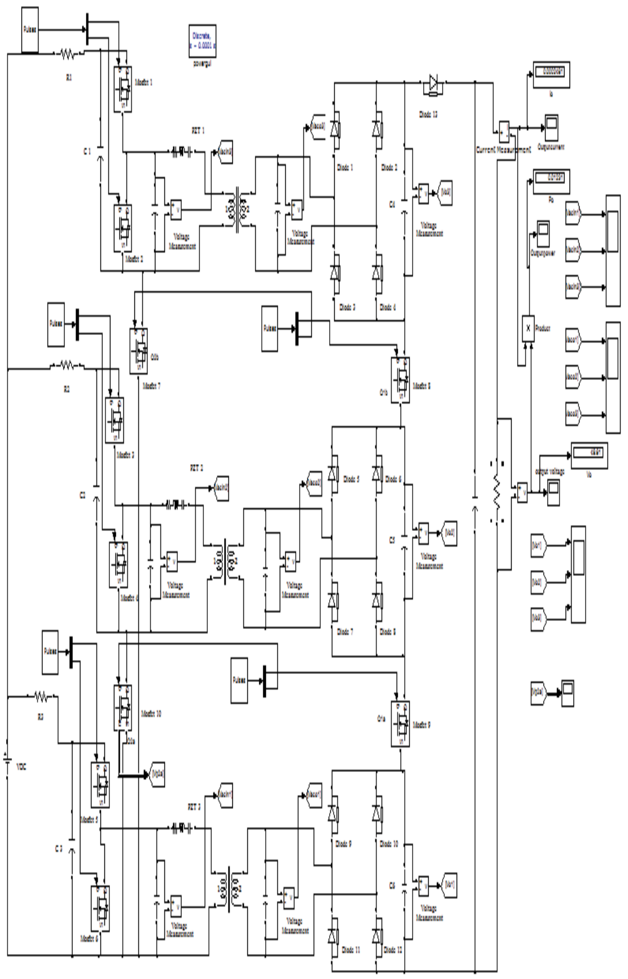

Figure 5: Simulation circuit diagram for three level piezoelectric transformer converters by using Rosen type.

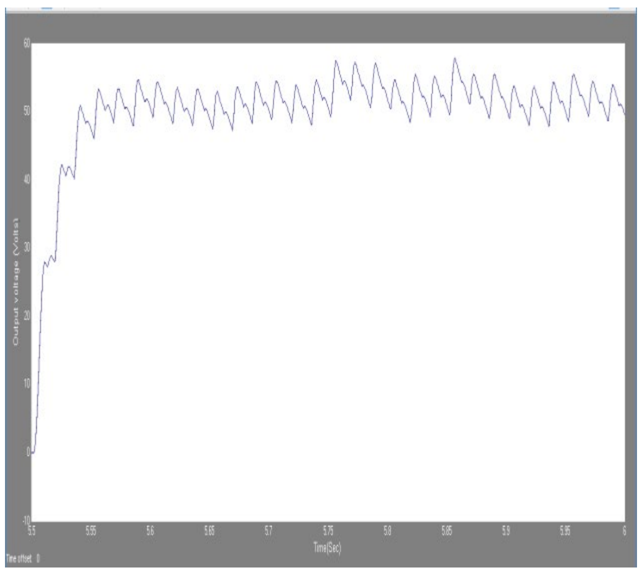

Figure 6: Output voltage wave form

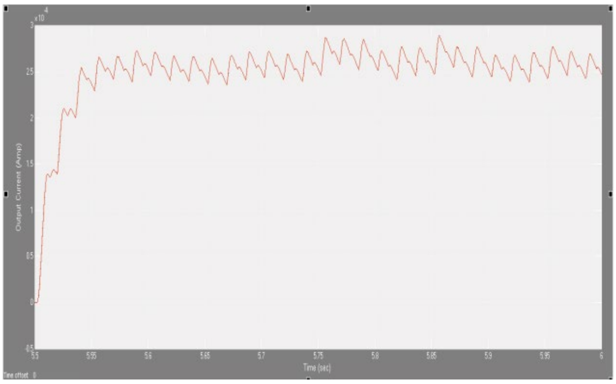

Figure 7: Output Current wave form

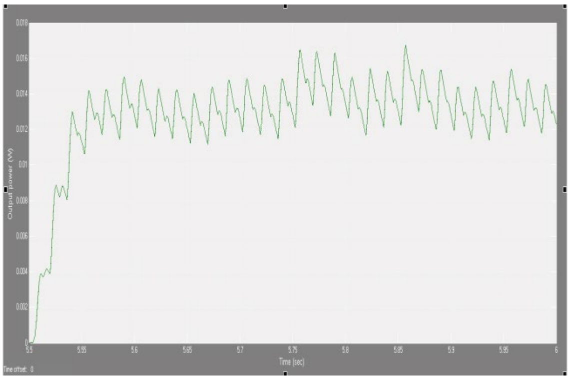

Figure 8: Output Power wave form

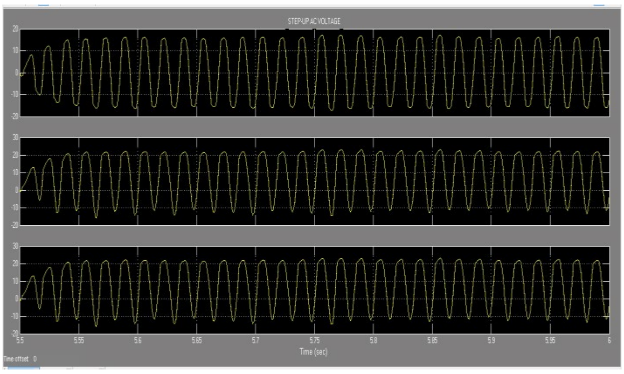

Figure 9: Step-up AC voltage wave form

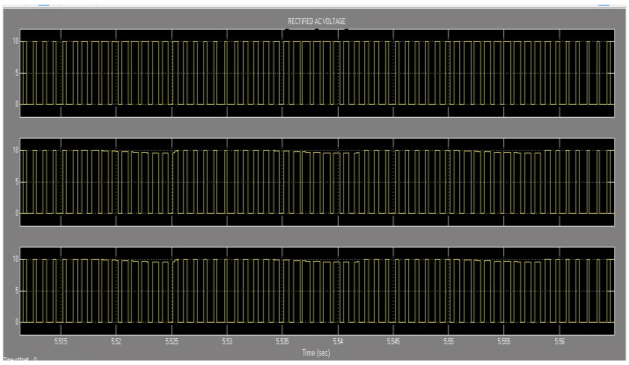

Figure 10: Rectified AC voltage wave form

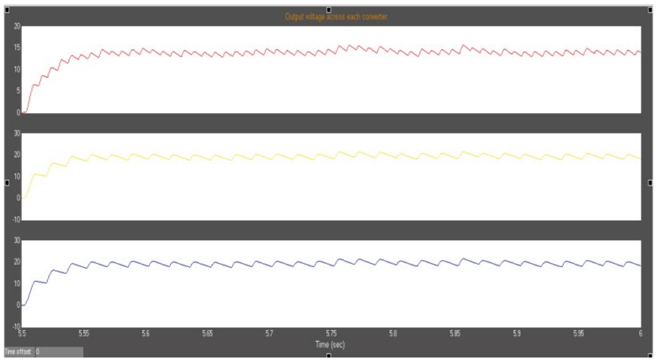

Figure 11: Output voltage wave form across each converter

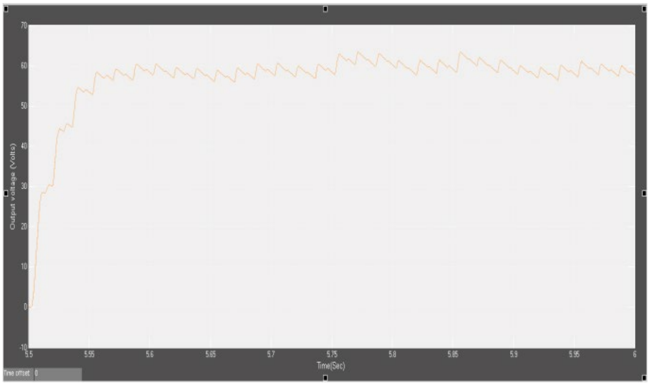

Figure 12: Output voltage wave form when R_L=500 KΩ

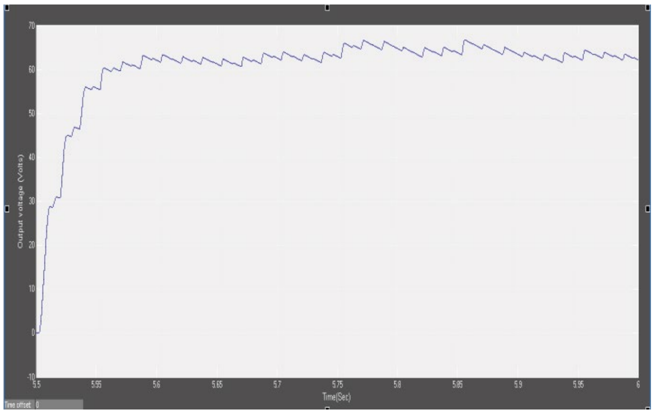

Figure 13: Output voltage wave form when R_L=1000 KΩ

S. No	Parameters	Value
1	V_{in}	10 V
2	R_{in}	1Ω
3	C_{in}	100 e-6
4	C_{pzt}	8.5 e-12
5	C_b	1 e-6
6	C_o	0.01 e-6
7	R_O	200KΩ

Table 1: Parameters of the Converter

S.No	Input voltage (Volts)	Load Resistance (KΩ)	Output voltage (Volts)	Output Current (Amps)	Output power (W)
1	10	100	41.39	0.0004139	0.01713
		200	49.61	0.0002481	0.01231
		400	55.98	0.00014	0.007835
		500	57.72	0.0001154	0.0006663
		1000	62.26	6.226*e-5	0.003877

Table 2: Three level piezoelectric transformer converters

output voltage, some frequency tracking mechanisms are necessary. This is because PT can be seen as a resonant conversion circuit.

In different conditions, it has an optimal frequency to derive maximum power or highest voltage output. It is a pleasure that many frequency tracking mechanisms have been presented in some literatures. The parameters of the PT model measured by short-circuit test are necessary to lock the optimal frequency range [11]. It tracks the optimal frequency to overcome parameters variation.

Modeling of Three Level Converter

The modeling of three level piezoelectric transformer converters by using Rosen type is shown in Figure 5.

The parameters of the three level piezoelectric transformer converters represented in Table 1.

Simulation Results

The three level piezoelectric transformer converters output voltage, output current and output power wave forms are shown I Figures 6-8. Where V_{in}=10v, R_L=200kΩ. From Figure 6 we can observe that the output voltage value is given by 49.61V. The three level piezoelectric transformer converters Step up AC voltage and Rectified AC voltage and V_o across each converter wave forms are shown in Figures 9-11 [12].

Similarly the three level piezoelectric transformer converters output voltages for Constant input (V_{in}=10V) and different load variations are shown in Figure 12 and 13. For constant input and different load variations of three level piezoelectric transformer converters V_0, I_o and P_o values are shown in Table 2.

Conclusion

Rosen-type PT and other non-isolated conversion circuits are widely applied to various occasions. But the common path problem between the input and the output connections is that the resulting multiple connections of non isolated convertor are not simple tasks. A method based on a special bootstrap method has been proposed in order to connect a number of outputs of non-isolated conversion circuits together which allows power to be delivered to output from different sub convertors. The objective of this paper is that through the analysis of multiple PTs convertor, to present a new method, which can obtain the summation of output voltage of multiple conversion circuits, which are based on common neutral between the input and output.

References

1. Yuanmao Y, Eric Cheng KW, Kai Ding (2012) A Novel Method for Connecting Multiple Piezoelectric Transformer Converters and its Circuit Application. IEEE transactions on power electronics 2: 1926-1935
2. Lin CY, Lee FC (1993) Development of a piezoelectric transformer converter.
3. Ivensky G, Zafrany I, Ben-Yaakov SS (2002) Generic operational characteristics of piezoelectric transformers. IEEE Trans. Power Electron 17: 1049-1057.
4. Piezoelectric Transformers in Power Electronics, IEEE transactions on power electronics.
5. Ivensky G, Bronstein S, Ben-Yaakov S (2004) A comparison of piezoelectric transformer ac/dc converters with current doubler and voltage doubler rectifiers. IEEE Trans. Power Electron 19: 1446-1453.
6. Alonso JM, Ordiz C, Costa MAD (2008) A novel control method for piezoelectric-transformer based power supplies assuring zero-voltage switching operation. IEEE Tran. Ind. Electron 55: 1085-1089.
7. S´anchez AM, Sanz M, Prieto R, Oliver JA, Alou P, et al. (2008) Design of piezoelectric transformers for power converters by means of analytical and numerical methods. IEEE Trans. Ind. Electron. 55: 79-88.
8. Lo YK, Pai KJ (2007) Feedback design of a piezoelectric transformer based half-bridge resonant CCFL inverter. IEEE Trans. Ind. Electron. 54: 2716-2723.
9. Liu YC, Chen YM (2009) A systematic approach to synthesizing multi input DC–DC converters. IEEE Trans. Power Electron. 24: 116-127.
10. Qian Z, Abdel-Rahman O, Al Atrash H, Batarseh I (2010) Modeling and control of three-port DC/DC converter interface for satellite applications. IEEE Trans. Power Electron. 25: 637-649.
11. Ho ST (2007) Modeling of a disk-type piezoelectric transformer. IEEE Trans. Ultrason., Ferroelect., Freq. Contr. 54: 2110–2119
12. Piezoelectric Transformer Model: ELS-60 Data Sheet, Eleceram Technology Co., Ltd., Taoyuan, Taiwan.