New Tunable Piezoelectric Transformers and their Applications in DC-DC Converter

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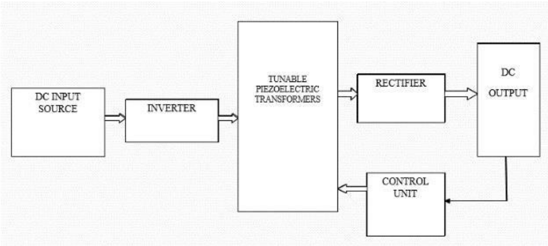
***Abstract* - This paper introduces a new tunable piezoelectric transformer (TPT) which provides an extra control terminal, used in this case, to regulate the output voltage. It demonstrates its operation in dc-dc converter application. Piezoelectric transformers(PTs) are solid- state devices that transform electrical energy into electrical energy by means of a mechanical vibration. These devices are manufactured by using Piezoelectric materials that are driven at resonance. Piezoelectric transformer is used in high voltage and low power applications. A mathematical analysis has to be done on electrical equivalent circuit of the TPT to understand the effect of the control terminal loading on the circuit performance. According to this analysis, a variable capacitor is connected across the control terminal is proposed to regulate the output voltage for line and load variation. For higher power ac-dc and dc-dc step down applications, radial type PTs have been developed.To control the voltage gain of the transformer, a new TPT has been developed featuring an auxiliary secondary terminal. The concept of 'Tunability' in a TPTs are introduced and mathematical conditions are derived to achieve the required tunability. This analysis can help the TPTs designer to design the TPT for a specific application and predict the load and line regulations limits for a given design. This paper introduces the design concept behind TPT based dc-dc converters, and proposes a control scheme for their implementation. A circuit implementation of the variable capacitor, intended for control is presented. With the proposed control circuit design, the effective value of a fixed capacitor can be controlled by controlling the duty cycle of a switch. This results in some exciting characteristics from a dc-dc converter standpoint, like an adjustable frequency response of the TPT, and fixed frequency control of the converter with no-cross talk between the primary and secondary terminal in the control circuit. The design of series input inductor for achieving zero voltage switching (ZVS) in the inverter switches for the new control is also discussed.**

Experimental results for two different TPT designs are presented. Their differences in structure and its effect on the circuit performance has been discussed to support the mathematical analysis.

Keywords: Piezoelectric transformer, Control unit, Rectifier, Inverter.

1. INTRODUCTION

Power electronics has been seen rapid developments in past two decades. The need for more efficient and compact technologies have been grown with the increase in an energy demand. The development of Rosen-type Piezoelectric transformerswith the high voltage gain become popular during the 1990's and the early 2000's in high-voltage low-power applications such as back lighting of cold cathode fluorescent lamps (CCFLs) used in liquid crystal displays (LCDs) in laptop computers. Magnetics are an essential cog for a wheel of power electronics. So that, extensive research is going on to magnetics miniature and to increase an efficiency for the system losses should be reduced. In 1950's Rosen have got up with an Piezoelectric transformer design [1]. After this a new Rosen-type has been used because of their capability to produce dc-dc converters with an high output voltage. Piezoelectric transformers is now seen as an replacement of a potential for the traditional magnetic transformer. In comparision of magnetic transformers, Piezoelectric transformers has the potential of being lighter and have an high power density, and it have to be prove for an suitable for the in an automated manufacturing, as well as its work in the presence of an high magnetic fields. It makes this very useful for an environment with an high ambient magnetic fields such as Magnetic Resonance Imaging machines where there is an presences of magnetic field and it will affect the work of an normal magnetic transformers. High voltage and low power potential transformers for its use in electronic ballasts will be only the achieveable success story of an PT based converters.



2. BLOCK DIAGRAM

The entire block diagram is an DC-DC converter and it converts fixed DC supply to variable DC supply.

Fixed dc supply is given as an input and this supply is taken to an inverter and the inverter converts dc supply to an ac supply. It changes to an ac supply for the purpose of giving the supply to tunable piezoelectric transformer. The control unit will sense the voltage that is needed for the load. After it senses the voltage, it sends a signal to the tunable piezoelectric transformer.

After this process, piezoelectric transformer will send the tuned voltage to the rectifier and finally the rectifier converts ac supply to dc supply and output will be taken as an variable dc supply.

3. EXISTING METHOD

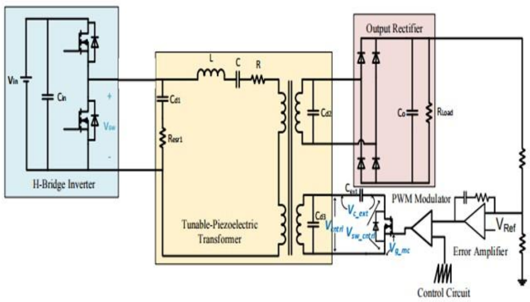
By change of switching frequency output voltages is regulated by the potential transformers. For different outputs there is an separate output converter. The combination of an pulse with modulation and pulse frequency modulation will be controlled to regulate the output voltage for large load ranges.

4. PROPOSED METHOD

As a radial piezoelectric transformer, the proposed tunable piezoelectric transformer uses the same structure. There is an additional piezoelectric section which is called as a control layer will be sandwiched between the primary and secondary terminals. Their will be a change in control capacitances which modifies the primary series capacitance of a control layer, thus by change of the resonance frequency of the piezoelectric transformer structure.

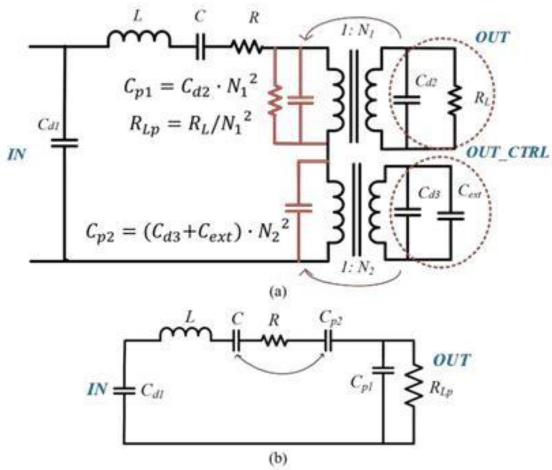
5. CIRCUIT DIAGRAM

In this dc-dc converter fixed dc supply is given an input and variable dc supply in an output.



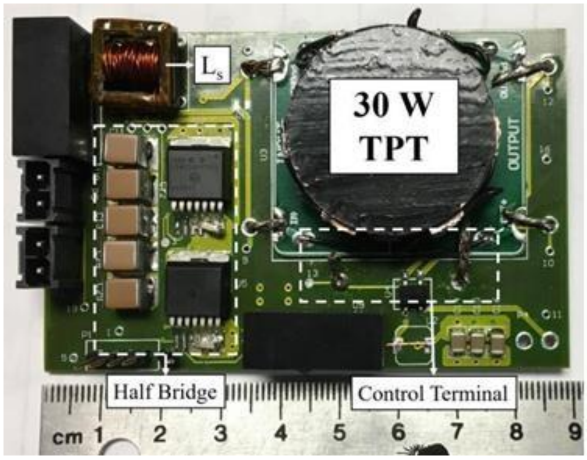
In this bridge inverter is used to convert dc supply to ac supply. AC supply is given to transformer. The required voltage for the load will be given as an feedback signal to an amplifier as an input and this input will be given to control unit and it will give the signal to the tunable piezoelectric transformer. The piezoelectric transformer will produce the required voltage that is needed for the load and it sends to an rectifier. The rectifier converts ac supply to dc supply and therefore output will be produced as an variable dc supply.

6. ELECTRICAL EQUIVALENT CIRCUIT



By using the electrical equivalent circuit the voltage gain characteristics of tunable piezoelectric transformer will be derived. The voltage gain characteristics of tunable piezoelectric transformer will depend on load operating frequency and input voltage.

7. HARDWARE REQUIREMENTS

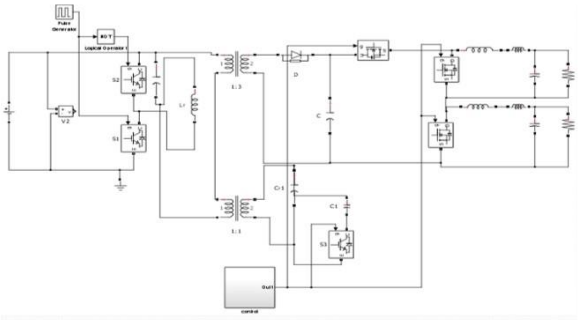


Capacitor: A device which is used to store the electric charge and it consists of one or more pairs of conductors which is separated by an insulator. The effect of capacitor is called as capacitance.

Resistor: It resist the follow of electric charges.

Control unit: Control unit is one of the component in the computers central processing unit and it directs an operation of the processor. I t instructs computer memory, arithmetic and logic unit, input and output device to response a program instructions. The computer resources will be managed by the control unit.

8. SIMULATION MODEL

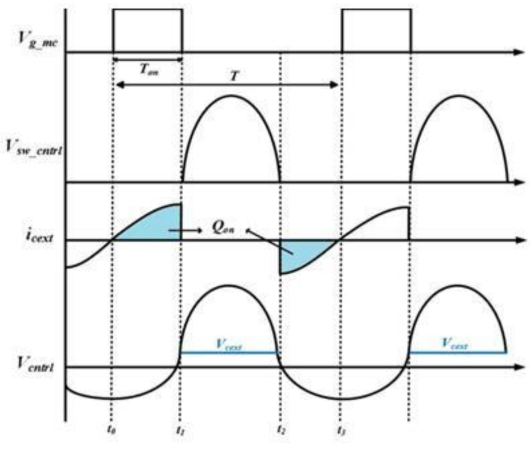


Simulation model has three modes of operation mode 1,mode 2,mode 3.

Mode 1: The triggering pulse is given to ON the MOSFET. When the MOSFET is switched ON, external capacitance will starts charging.The voltage across an internal control capacitor will continues to rise by following the input voltage.

Mode 2: The triggering pulse is given to switch OFF the MOSFET. When the MOSFET is switched OFF, the external capacitance will disconnected from the control terminal and the voltage will be maintained constant.

Mode 3: In this control voltage will fall below Vcext and external cap will now start to discharge with an anti-parallel diode of a MOSFET. The negative current will flow through the diode of an control MOSFET will enables Zero Voltage Switching (ZVS) in the control switch. The next switching cycle will begins at this mode.



There will be some of the key waveforms in the control terminal the effective value of the capacitor will be determined by the charging and discharging time interval of an external capacitor. By assuming an sinusoidal nature of current the effective value of capacitance can be derived. By using an equation the duty cycle of the control MOSFET can be varied.

9. CONCLUSION

In this paper, there is an detailed understanding of the operation on tunable piezoelectric transformer. To derive the important relation between an circuit and the performances. By adding an variable capacitor, it proposed a way to tune a transformer. For calculating the tunability the importance equation can be derived. Thus the detailed procedure of design for dc-dc converter using the tunable piezoelectric transformer.

REFERENCE

[1] R.-L. Lin, "Piezoelectric transformer characterization and application of electronic ballast," PhD Dissertation, Electrical Engineering, Virginia polytechnic institute and state University, Blacksburg, 2001.

[2] A.V Carazo, "Piezoelectric Transformers: An Historical Review," in *Actuators*,2016, switched-capacitor circuit," in *2013 1st International Future Energy Electronics Conference* vol.5, no. 2, p. 12: *(IFEEC)*, 2013, pp. 691-696. MultidisciplinaryDigital Publishing Institute.

[3] T. Ninomiya, M. Shoyama, T. Zaitsu, and T.Inoue,"Zero-

[4] J. M. Alonso, C. Ordiz, and voltage- switching techniques M. A. D. Costa, "A Novel and their application to high-Control Method for frequencyconverter with Piezoelectric-Transformer Based piezoelectric transformer," in PowerSupplies Assuring Zero - *Industrial Electronics, Control* Voltage-SwitchingOperation," *ndInstrumentation,1994. IEEE Transactions on Industrial IECON '94., 20th International Electronics*, vol. 55, no. 3, pp. *Conference on*, 1994, vol. 3, pp. 1085-1089, 2008. 1665-1669 vol.3.

[5] S. Hamamura, D. Kurose, T. Ninomiya, and M. Yamamoto, "New control method of piezoelectrictransformer converter by PWM and PFM for wide range of input voltage," in *7th IEEE International Power Electronics Congress. Technical Proceedings. CIEP 2000 (Cat. No.00TH8529)*, 2000, pp. 3-8.

[6] T. Zaitsu, T. Shigehisa, M. Shoyama, and T. Ninomiya, "Piezoelectrictransformer converter with PWM control," in *Applied Power Electronics Conference and Exposition, 1996. APEC '96. Conference Proceedings 1996., Eleventh Annual*, 1996, vol. 1, pp.279-283 vol.1 V. Carazo, "Piezoelectric converters for DC/DC and AC/DC applications," in *Portable Power Developers Conference*, San Jose, CA, USA, 18–20 April 2005.

[7] Y. Hu, A. Amara, and A. Ioinovici, "LLC resonant converter operated at constant switching frequency and controlled by means of aE. L. Horsley, A. V. Carazo, M. P. Foster, and D. A. Stone, "A Lumped Equivalent Circuit Model for the Radial Mode Piezoelectric Transformer," in *2009 Twenty- Fourth Annual IEEE Applied Power Electronics Conference and Exposition*, 2009, pp.1747- 1753.

[9] J. M. Alonso, C. Ordiz, and M. A. D. Costa, "A Novel Control Method for Piezoelectric-Transformer Based Power Supplies Assuring Zero- Voltage-Switching Operation," *IEEE Transactions on Industrial Electronics,* vol. 55, no. 3, pp. 1085-1089, 2008.

[10] E. M. Baker, W. Huang, D. Y. Chen, and F. C. Lee, "Radial mode piezoelectric transformer design for fluorescent lamp ballast applications," in *2002 IEEE 33rd Annual IEEE Power ElectronicsSpecialists ConferenceProceedings (Cat. No.02CH37289)*, 2002, vol. 3, pp. 1289-1294 vol.3.