INVESTIGATION OF RESONANCE INDUCTIVE-CAPACITIVE TRANSDUCERS BASED ON BOUCHEROT CELL FOR POWER CAPACITORS CHARGING

Kostadin MILANOV* and Michaela SLAVKOVA**

*Technical University of Sofia, Department of Electrical Apparatus, 1156 Sofia, Bulgaria, E-mail: k.milanow@abv.bg

**Technical University of Sofia, Department of Electrical Apparatus, 1156 Sofia, Bulgaria, E-mail: michaela_ds@tu-sofia.bg

Abstract. The charging of power capacitors is more efficient if a current source is used. The transducers with voltage feedback regulation have wide applications in this area and meet the standard requirements. The aim of this paper is the investigation of resonance inductive-capacitive transducers based on Boucherot cell for charging of power capacitors.

Keywords: Boucherot cell, magnetizer, power capacitor, capacitor charging, transducers.

INTRODUCTION

The charging of power capacitors that are characterized by high accumulated energy has specific features. They result in the fact, that the usage of voltage sources is inefficient. As it is shown in the electrical engineering classical courses and in specialized publications, the efficiency coefficient of the process of capacitor charging via voltage source is 50% [1]. To avoid the energy losses, in charging of capacitors, the current sources should be used. In real applications the current sources are realized by special transducers which are powered by the classical voltage sources. There is a widespread application of semiconductor transducers with feedback for stabilization of their output current. The phase control transducers are applied – transducers with thyristors, as well as pulse transducers with PWM (pulse width modulation) or current tracking regulation. In the complex requirements of modern power supplies for low losses, low levels of the generated harmonics in electrical main currents and high reliability, the resonance inductive-capacitive voltage-current transducers proposed by French inventor P. Boucherot at the end of 19th century unreasonably rarely are used, despite their undoubted advantages in many applications [2].

The aim of the presented paper is to conduct a research on the operation of inductive-capacitive transducers based on Boucherot cell for charging of power capacitors for magnetizers. There are other applications of these transducers such as these: in power supply of welding equipment, for power arc furnaces, laser devices, etc [3]. To the author is not known such study of these transducers for application in charging of power capacitors with stored energy exceeding tens of kJ.

ANALYSIS AND PROJECT DESIGN

In Fig. 1 is shown one of the three proposed schemes of P. Boucherot resonance inductive-capacitive transducers "voltage - current". To achieve the task set out in this work, this classic design is perfectly suitable. It is not necessary to use solutions with inductive coupled chokes and other more sophisticated options such as bridge circuits designed to achieve high accuracy of stabilization of the output current [3], [4] [5].

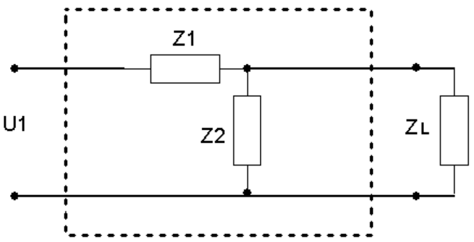

Figure 1. . Boucherot scheme.

The transducer itself consists of two impedances – Z_1 and Z_2 that are connected in series and supplied by mains. The load – Z_L - is connected in parallel with the impedance Z_2. This variant of the transducer has an advantage that is achieved by means of standard components - capacitors and chokes without special performance, which favors the application of the idea. The basic electrical scheme of the transducer is shown in Fig. 1. It is easy to estimate the electrical current through the load via The venin's theorem.

$$I_L = \frac{U_1 \dfrac{Z_2}{Z_1 + Z_2}}{Z_L + \dfrac{Z_1 . Z_2}{Z_1 + Z_2}} \quad (1)$$

Based on the Boucherot's concept, both impedances Z_1 and Z_2 must be reactive elements (inductive and capacitive elements) adjusted in resonance with the frequency of the supply voltage, i.d.

(2) $$\overset{*}{Z}_1 + \overset{*}{Z}_2 = 0$$

In this condition the electrical current through the load is obtained as:

(3) $$I_L = \frac{U_1}{Z_1}$$

The electrical current through the load does not depend on the value of the load impedance and will be determined by the supply voltage and the transducer parameters |Z1|=|Z2|.

The electrical scheme for charging of power capacitors is given in Fig.2. It meets the requirement for galvanic separation of the charging electrical circuit from the mains via isolating and matching transformers. It also meets the requirement to be carried out the charging with voltage that significantly exceeding the supply voltage

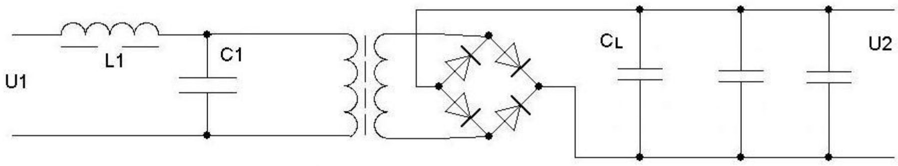

Figure 2.Electrical scheme for power capacitor charging.

The transformer is used to increase the voltage to which the power capacitor is charged compared to the mains' voltage and also to provide a galvanic separation. For dimensioning of the electrical circuit elements it is necessary to set the charging time - t_m. This is the required time to reach the maximum charge voltage U_m and the capacitance C_L. The average value of the charging electrical current, on condition that it is supported invariable by the transducer, is determined by the expression:

(4) $$I_{LAV} = \frac{C_L.U_m}{t_m}$$

The reffered value of the charging current that appears to the primary circuit is determined by the transformer turns ratio k_{TR}. The values of the reactive elements L_1 and C_1 are determined by the assumed supply voltage and its frequency f, respectively $\omega=2\pi f$, the reffered value of the necessary charging current to the primary circuit average value I_{LAV}. The value of transformer turn ratio is determined by the necessary maximum voltage for power capacitor charging. The value of the current form factor k_f

is considered to be equal to that of a sinusoidal wave as the primary current of the transducer is sinusoidal. The following ratio is valid:

$$\omega L_1 = \frac{1}{\omega C_L} = \frac{U_1}{I_{LAV}} k_{TR}.k_f \quad (5)$$

The scheme in Fig. 2 is investigated by computer simulation with the software product PSpice. The PSpice diagram for computer simulation is given in Fig.3

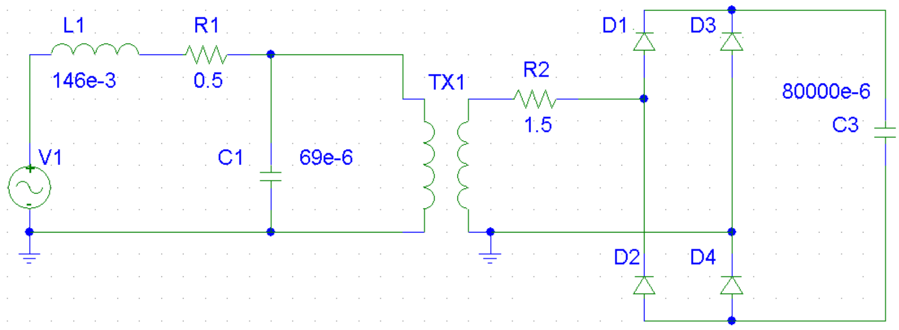

Figure 3. PSpice electrical simulation diagram.

The values of the elements are determined by expressions (4), (5) under the following initial conditions:

$U_1=230V_{RMS}$ $U_{1m}=325V$ $f=50Hz$ $I_{LAV}=4.5A$ $k_{TR}=4$

In Fig. 4 is shown the variation of the output voltage of power capacitor.

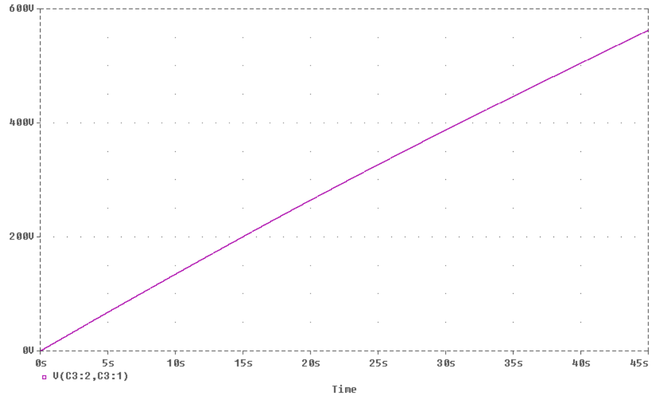

Figure 4. The output voltage of power capacitor amends by linear law.

It is seen that the voltage of the power capacitor amends by a linear law. This means that the charging current value is invariable. In Fig. 5 is shown the charging currents variation of the power capacitor (the top graph) and the current through the input inductance (that flows from the mains). These results confirmed that the charging current has invariable value and it is sinusoidal to the mains.

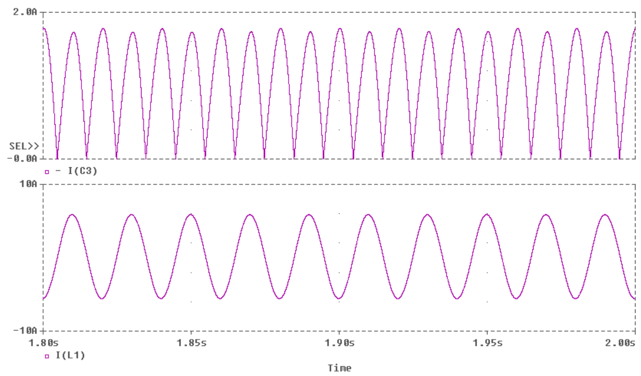

Figure 5. The variation of the charging currents.

Such a resonance inductive-capacitive transducer as this one given in the test circuit is implemented, deployed and operated for over 10 years. The power capacitor which is charged with the transducer is used for pulsed power supply of a magnetizer based on rare earth permanent magnets and has a capacity of 80 mF. The investigated experimental results fully confirm theoretical and simulation results.

CONCLUSIONS

The theoretical and simulation analysis that was carried out, show that resonance inductive-capacitive transducers based on at P. Boucherot cell are suitable for charging of power capacitors. These transducers are supplied by the mains and the current that flows through them is sinusoidal. They do not generate harmonic components in electrical current and therefore they do not generate interference. Also they do not cause additional losses in power systems. The simplified structure and the long practical observations of the authors on the operation of this transducers show that they are extremely reliable in operation and is recommended for wider application.

REFERENCES

[1] Maxwell Technologies, *Application Note Doc*. 1008981, 12/2005

[2] Boucherot P., *La Lumiere electrique*, t 45, 1892, N 27-39

[3] Милях, А.Н., Б.Е. Кубышин, И.В. Волков, *Индуктивно-емкостные преобразователи источников напряжения в источники тока*, Наукова думка, Киев - 1964

[4] Steinmetz, *Theory and Calculation of Alternating Current Phenomena*, McGraw Hill, 1908

[5] Николова, К., Н. Трифонов, *Преобразовател на трифазна система променливи напрежения, в източник на постоянен ток, изпълнен с приложение на схема „Бушеро"*, Годишник на Техническия университет – София, том 60, кн. 1., 2010 г. стр.183 - 190