THE TEST AND MEASUREMENT DEVICES FOR HIGH VOLTAGE

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Abstract: High voltage presents a very perspective area of the power engineering. The test and measurement devices for high and very high voltages are typically located in a large measuring and testing laboratories. So their requirements for space and financial costs are huge. In my project, these devices are created on a small scale, but they are fully functional and it is possible to perform measurements as on a commercial devices. Of course, at lower voltage levels.

Keywords: High voltage, power engineering, laboratory, measurement device

1. INTRODUCTION

Development and production of equipments for the high voltage laboratory is realized with the support of the project for research of renewable sources (CVVOZE). Under this project was first built the high voltage test cell. This cell satisfies the safety requirements for working with high voltage. After the completion of the cell we came to the realization of power supplies. As the first source was realized a high voltage AC power source 2x6 kV AC. This power source can be operated at maximum load of 600 W. In addition to this source was built the rectifier with multiplier and capacitor filter, operating to the maximum voltage 30 kV DC. For purposes of measuring at these voltage levels was designed and realized the combined RC voltage divider. The divider can be operated at maximum input voltage 100 kV, its input capacitance is 7 pF. As a source of high frequency equipment were implemented two Tesla coils. As the first was created a small Tesla coil with a maximum power input 200 W, pulse driven and with the maximum output voltage 100 kV. A second larger version of the Tesla coil is already realized with the continuous or pulsed driving. The coil can be operated at working frequency 130 kHz, its maximum input power is 3 kW and a maximum achieved output voltage is about 700 kV. As a representative of laboratory pulse generator was designed and constructed the Marx generator with seven stages by 20 kV and with its maximum output energy 1 J. All this HV equipments are designed according to the theory described in [1, 2, 3].

2. HIGH VOLTAGE LABORATORY EQUIPMENT

2.1. THE HIGH VOLTAGE TEST CELL

As it was written in the introduction, so main part of the project was designed and constructed the high voltage test cell. The main importance here was taken of the simplicity of design and especially on the safety, which is in the first place at work with the high voltage. For the cell was chosen a full room height, ie 3.2 m, to maximize the provided space. In addition, the floor dimensions were chosen due to the disposition a reserved room 2.5 x 2.5 m. A perimeter "fencing" of the cell reaches a height of 2 m from the floor.

The cell is powered by mains power supply 3x400 V AC, max. 25 A. The output voltage can be smoothly regulated by the 3 phase transformer and with a contactor switching using the two stop buttons is guaranteed a quick and safe stop. At Figure 1 is shown the cell design in Google - SketchUp and the resulting realization with the visible security elements including the warning signs.

Fig. 1: Design and realization of the high voltage cell.

2.2. THE AC POWER SUPPLY 2X6 KV

This supply was designed as the main high voltage power supply with output voltage 12 kV (2x6 kV to ground). The maximum power load of the source is 600 W, 1 kW in short time. Its triac control enables control of output current. However, this supply does not have a short circuit protection, so it is necessary to protect it against long term output short circuit.

The source is implemented in a practical portable case. With its light weight is easily portable. The final design with including the closed version is shown at Figure 2.

Fig. 2: Design and realization of the AC Power Supply 2x6 kV.

2.3. THE HIGH VOLTAGE RECTIFIER WITH MULTIPLIER AND CAPACITOR FILTER

The high voltage rectifier with multiplier is used to increase the output voltage and directing the output current of the AC source described in the previous Chapter 2.2. From the output voltage 12 kV AC is created twice of peak voltage by the following formula (1).

$$V_{DC} = 2\sqrt{2} \times V_{AC} = 2\sqrt{2} \times 12\text{kV} = 33{,}94\text{kV} \qquad (1)$$

However, is necessary to count with a lower efficiency of transformation and losses in single parts of the rectifier and multiplier, so the output voltage will be approximately 30 kV DC. The total energy in the output of capacitor at full voltage is about 80 J. And the final design of rectifier with capacitor filter is shown at Figure 3.

Fig. 3: The high voltage rectifier with multiplier and capacitor filter

2.4. THE COMBINED RC VOLTAGE DIVIDER

The combined voltage dividers are commonly used to measure both high voltages DC and AC in the laboratory of high voltage. If the divider is well designed, works as a frequency-independent. The maximum input voltage of this divider is 100 kV. Its input capacitance is 7 pF and the maximum operating frequency is 50 kHz. Its dividing ratio is 1:10000, so the maximum output voltage is 10 volts, which can be without problems connected to a high frequency voltmeter or oscilloscope. The final design of the combined RC voltage divider is shown at Figure 4.

Fig. 4: The high voltage RC divider

2.5. THE MARX PULSE GENERATOR WITH 7 STAGES

The Marx generator is used to generate high voltage up to several MV in the laboratory of high voltage. This generator uses a parallel capacitor charging each of its stages and then the serial discharge. Thereby it can be obtained the resulting high voltage pulse. At each stage of the model generator is 1 nF capacitor at 20 kV. When the generator is powered at 20 kV high voltage the pulse will appeared of approximately 100 kV at the output. When we consider the losses, the output voltage is lower than expected 7x20 kV. The final design of the Marx pulse generator is shown at Figure 5.

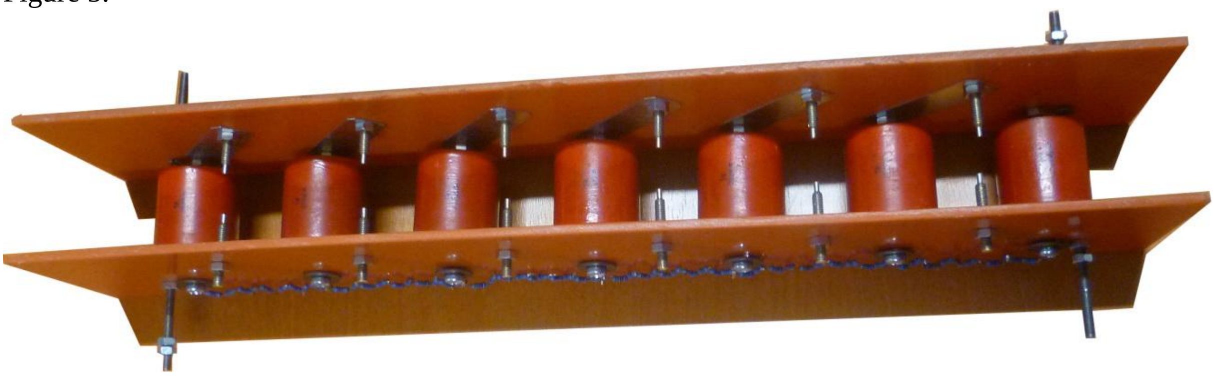

Fig. 5: The Marx pulse generator with 7 stages

2.6. THE TESLA COIL VERSION (NO.1)

The Tesla coil is used to generate high voltage with high frequency. Its resonant frequency depending at the size and design, varies from tens of kHz to MHz. The Tesla coil works as two resonant circuits (primary and secondary), which are air linked. The resonant frequency is fixed by the secondary coil structure, which we can change only a little (about tens of percents).

The Tesla coil (No.1) was created with a pulse driving, with the maximum input power 200 W and with the maximum output voltage 100 kV. Its output power is regulated by pulse width at constant frequency. Output voltage is regulated by changing the input voltage. The resonant frequency is about 300 kHz. Its driver is made in a compact version with maximum supply voltage 30 V DC. The final design of the Tesla coil version (No.1) with its driver is shown at Figure 6.

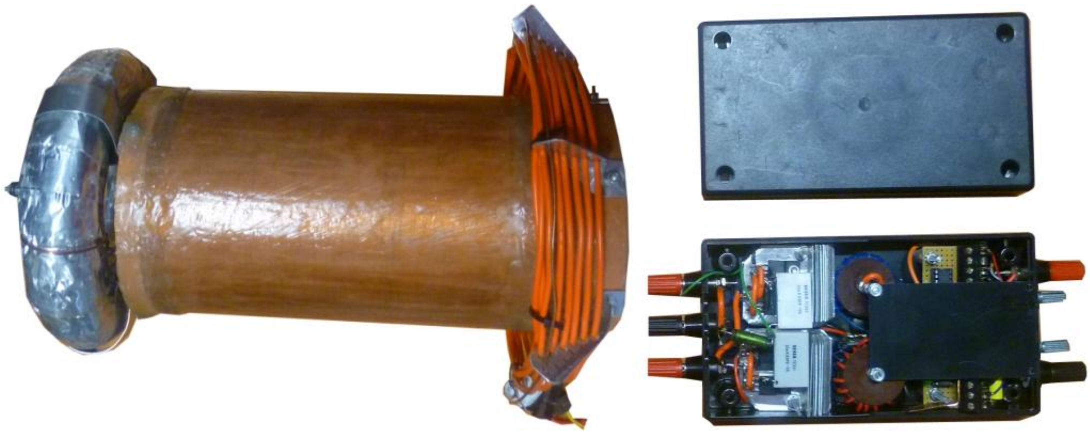

Fig. 6: The Tesla coil (No.1) with the driver

2.7. THE TESLA COIL VERSION (NO.2)

The Tesla coil (No.2) can be powered by a higher power, up to 3 kW. Its driver can work at continual or pulse driving. Its resonant frequency is about 130 kHz and for this time it was reached the maximum size of the output voltage approximately 700 kV. The Tesla coil (No.2) with driver and the control unit is shown at Figure 7.

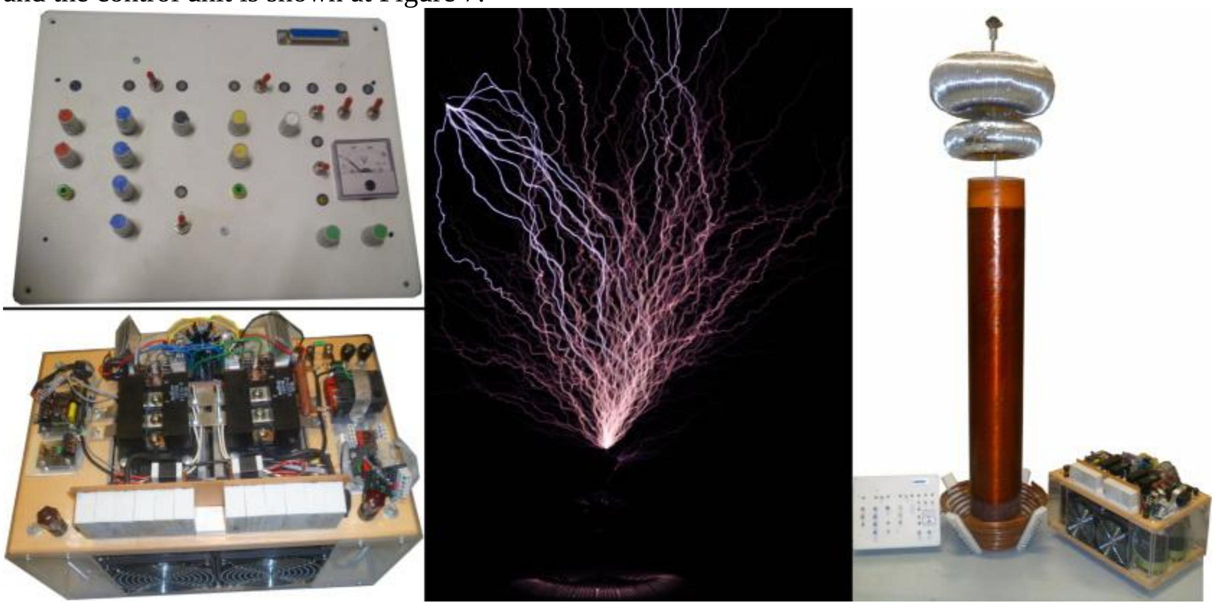

Fig. 7: The Tesla coil (No.2) with the driver and the control unit

3. THE FUTURE DEVELOPMENT OF EQUIPMENT AT HIGH VOLTAGE LABORATORY

Future development of laboratory equipment can be expected in the pulse generators. Further development is in the creation of a pulse generator with a predefined output waveform voltage or current. These pulse generators will be used for testing equipment and to verify the functionality of the overvoltage protections. The next development will also increase the performance of individual power supplies.

4. CONCLUSION

This article provides information about constructed devices which are parts of the high voltage cell located at the Department of Power Engineering, Faculty of Electrical Engineering and Communications.

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