THE POWER HIGH VOLTAGE CAPACITIVE DIVIDER

Michal Krbal
Doctoral Degree Programme (3), FEEC BUT
E-mail: xkrbal00@stud.feec.vutbr.cz

Supervised by: Petr Baxant
E-mail: baxant@feec.vutbr.cz

Abstract: The voltage dividers are used for the high voltage measurements in the test rooms and the high voltage laboratories. In the laboratories are used two types of high voltage dividers. The first type is a resistor divider, which is cheaper and simpler. But it is used to measurement to the lower frequencies down to 100 kHz and lower voltages typically below 100 kV. The second and most common type is a high voltage capacitive divider. By this divider can be measured voltages up to the order of MV, unlike the resistor divider. This divider is suitable for the measurement of high voltage in the frequency domain from the mains frequency of 50/60 Hz up to the order of MHz. However the capacitive is unsuitable for the measuring frequencies below the mains frequency, measuring DC voltage and the signals with the DC offset. The capacitive divider in such cases allows transient only. And in the way of the constant voltage in the input the divider provide a zero voltage in the output. The measurements of the DC and high frequency signals are allowed by the third type of resistor-capacitive (mixed) dividers.

Keywords: High Voltage, Capacitive Divider, High Frequency

1. THE DESIGN OF DIVIDER

The high voltage capacitive dividers are described by the value of capacity of high-voltage part, dividing ratio, wide frequency bandwidth and by the maximum of input voltage usually in the dependence on the input signal frequency. The signals of the mains frequency and the frequencies to 1 kHz can be measured continuously. At the higher frequencies is expected only the pulse character of the measured signal. If such the signal was the long time or continuous character, the divider would be overload and overheating or would be destroyed the source of signal. The amount of current flowing through a divider is shown in the following Table 1. The power losses in the divider are shown in the Table 1 as well. The divider is operated on the RMS voltage of 100 kV and the capacity of its high-voltage part is 1200 pF, maximum capacitive power losses are 100 kVAr. The dividing ratio of divider is 1:1000, so the capacity of the low-voltage part can be neglected.

Table 1: The value of current through the divider 1200 pF/100 kV depending on frequency

Frequency	**Susceptance**	**Current**	**Capacitive Power Losses**
f *(kHz)*	B *(kΩ)*	I *(A)*	Qcap *(kVAr)*
0.05	2653.928	0.038	3.768
0.4	331.741	0.301	30.144
1	132.696	0.754	75.360
3	44.232	2.261	226.080
10	13.270	7.536	753.600
30	4.423	22.608	2260.800
100	1.327	75.360	7536.000
300	0.442	226.080	22608.000
1000	0.133	753.600	75360.000
3000	0.044	2260.800	226080.000

From the Table 1 is evident that the capacitive divider is suitable for continuous measurement of the signal to 1 kHz at the operating voltage 100 kV. The value does not exceed 1 A, if current passing through the divider, and the capacitive power losses are below 100 kVAr. The divider is therefore unusable for frequencies above 1 kHz. To measure a signal of higher frequencies is necessary to reduce the value of input voltage or reduce own capacity of divider or use the divider with higher value of the passing current.

The solution of this problem is to create a divider with low input capacity, low dielectric losses and with the high value of passing current. The vacuum or ceramic capacitors seem to be the best. Unfortunately, the vacuum capacitors have low levels of capacity. The divider was finally realized from the ceramic capacitors. Six capacitors were used, so the divider has 6 stages. The nominal capacity of each stage is 500 pF, however, due to tolerance the mean value of capacity is 420 pF. The total capacity of the high-voltage part of divider is 70 pF only. The parameters of each stage of divider are shown in the Table 2. The capacitors are manufactured in Hungary in 1988 and are marked TGL 200/700. Their original use was to powerful oscillators and transmitters, their parameters can be for the short-term greatly exceed thanks to their high reliability and robust design. For example, each capacitor can withstand continuous 50 kVDC.

Table 2: The parameters of capacitive divider 70 pF/100 kV depending on frequency

Frequency f *(kHz)*	0.05	30	100	1000
Max. RMS voltage U *(kV)*	20	16.8	15.5	13
Max. RMS current I *(A)*	65	65	65	6
Max. Cap. Power Q *(kVAr)*	1000	1000	1000	

The amount of current flowing through a six-stage divider is shown in the Table 3. The Table 3 is created for the input voltage of 100 kV RMS, however the divider can be operated at maximum 80 kV RMS at a frequencies higher than 100 kHz.

Table 3: The value of current through the divider 70 pF/100 kV depending on frequency

Frequency	**Susceptance**	**Current**	**Capacitive power losses**	**C. Losses of 1 stage**
f *(kHz)*	B *(kΩ)*	I *(A)*	Qcap *(kVAr)*	Qcap *(kVAr)*
0.05	45495.905	0.002	0.220	0.037
0.06	37913.254	0.003	0.264	0.044
0,4	5686.988	0.018	1.758	0.293
1	2274.795	0.044	4.396	0.733
3	758.265	0.132	13.188	2.198
10	227.480	0.440	43.960	7.327
30	75.827	1.319	131.880	21.980
100	22.748	4.396	439.600	73.267
300	7.583	13.188	1318.800	219.800
1000	2.275	43.960	4396.000	732.667
3000	0.758	131.880	13188.000	2198.000

The six-stage divider can be permanently connected to the signal 1 MHz at 100 kV RMS. And the divider is overloaded at frequency of 3 MHz.

2. THE DRAFT CONSTRUCTION OF CAPACITIVE DIVIDER

The draft of divider is created by using the free program Google SketchUp. The main parts of divider are the six ceramic capacitors, four plastic carrier pipes, the input electrode and the low-voltage part. The total height of the divider is 900 mm with the input electrode. And the total width of the divider is approximately 250 mm, the width of each capacitor is 196 mm and its height is 30 mm. The vertical distance between two stages is 120 mm and it is the sufficient distance at maximum voltage levels RMS 20 kVAC or 30 kVDC.

The construction of divider is realized without some sharp edges. In order to achieve the homogenous distribution of the electric field is a top of divider mounted by semi-spherical electrode of height of 100 mm and width of 200 mm. The demonstration of design of divider is shown in the following Figure 1 in the Google SketchUp software.

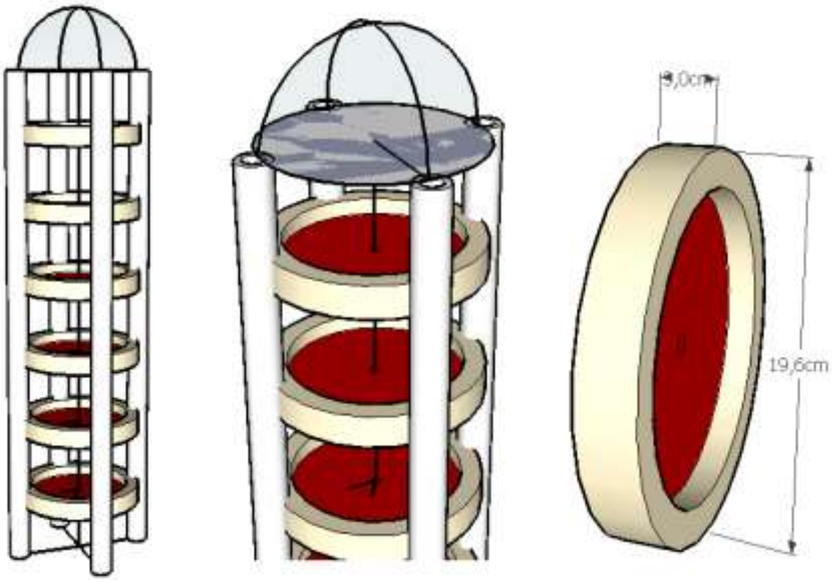

Figure 1: The design of capacitive divider in the SketchUp software

3. THE FINISH CONSTRUCTION OF CAPACITIVE DIVIDER

The whole construction of the capacitive divider is mechanically very stable, weight does not exceed 10 kg. Mechanical locking is done at the bottom, middle and top part of divider. On top of the input electrode is the connecting bolt. The low-voltage part of capacitive divider is composted from 32 pieces of foil capacitors 2.2 nF/400 V and the resulting value of capacity is approximately 70 nF. All conductive parts of divider are joined with solder. The maximum value of the current through the divider is 100 A. The finished photos of divider, the detail upper electrode and low-voltage part are shown in the following Figure 2.

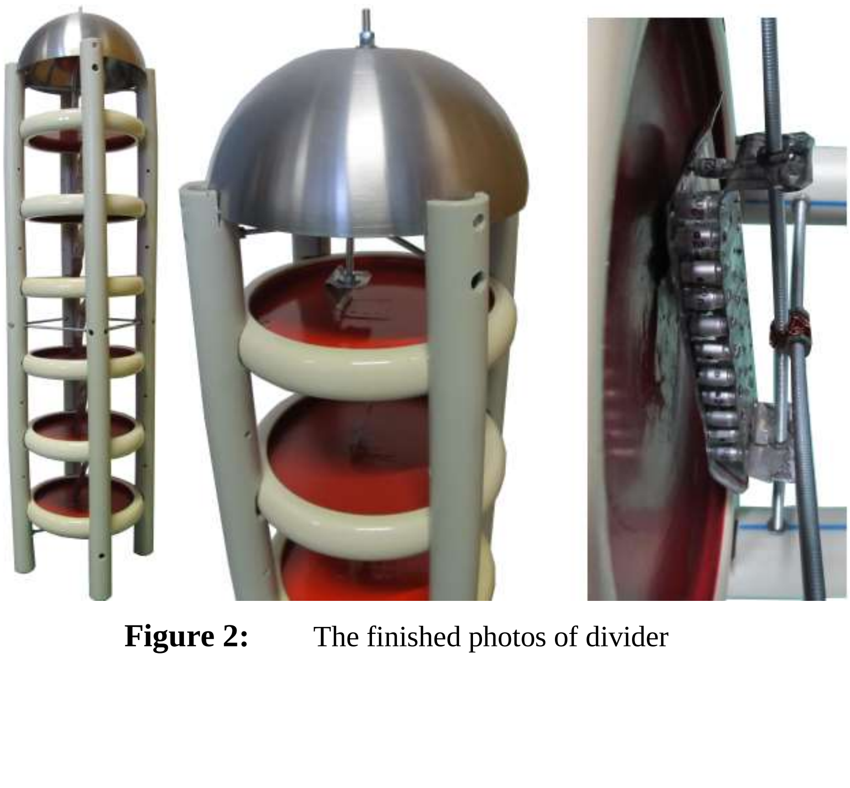

Figure 2: The finished photos of divider

4. THE DISTRIBUTION OF INSTESITY OF ELECTRIC FIELD AROUND DIVIDER

The magnitude of the electric field near the divider is the important and monitored parameter. If the intensity of electric field exceeds the dielectric strength of air, the release energy will be occurred. This phenomenon appears at sharp edges of devices. This leakage of energy is dependent on the value of voltage and frequency. Therefore, it is necessary to minimize the leakage, that the measurement was accurate as possible.

The intensity of electric field must to be evenly decreasing along the divider. If it were not, it would not be evenly distributed the voltage drop at the individual stages of the divider. The distribution of intensity of electric filed around the divider is shown in following Figure 3. Values are measured with 50 mm spacing. The units of intensity electric field are V/mm. All values measured at input voltage 20 kVAC RMS 50 Hz.

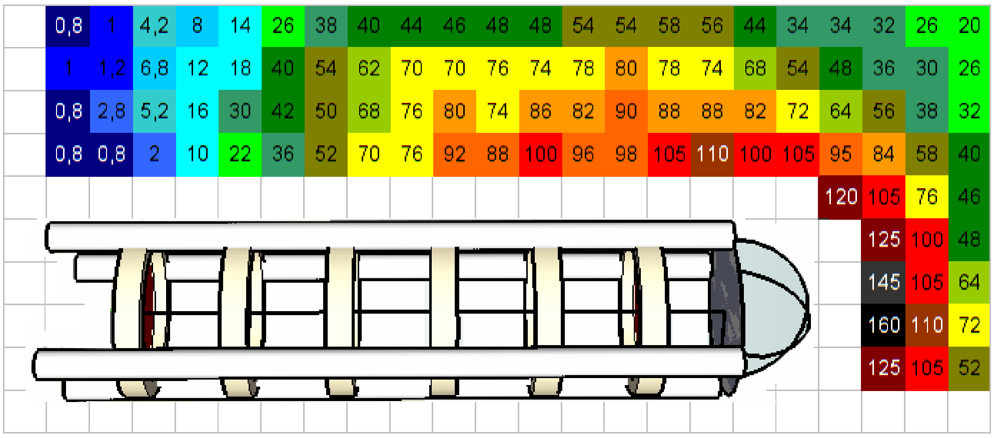

Figure 3: The distribution of electric field around the divider

The figure shows that at any point around the divider does not exceed the allowable intensity of electric field 1 kV/mm. The intensity is distributed approximately evenly along the divider.

5. THE MEASURED RESULTS BY CAPACITIVE DIVIDER

To allow measure by the divider at different frequencies, it is necessary to measure the frequency response of divider. Ideally, there should be a constant dependence of dividing ratio of divider on the frequency. The dependence of the dividing ratio on the frequency is shown in next Figure 4.

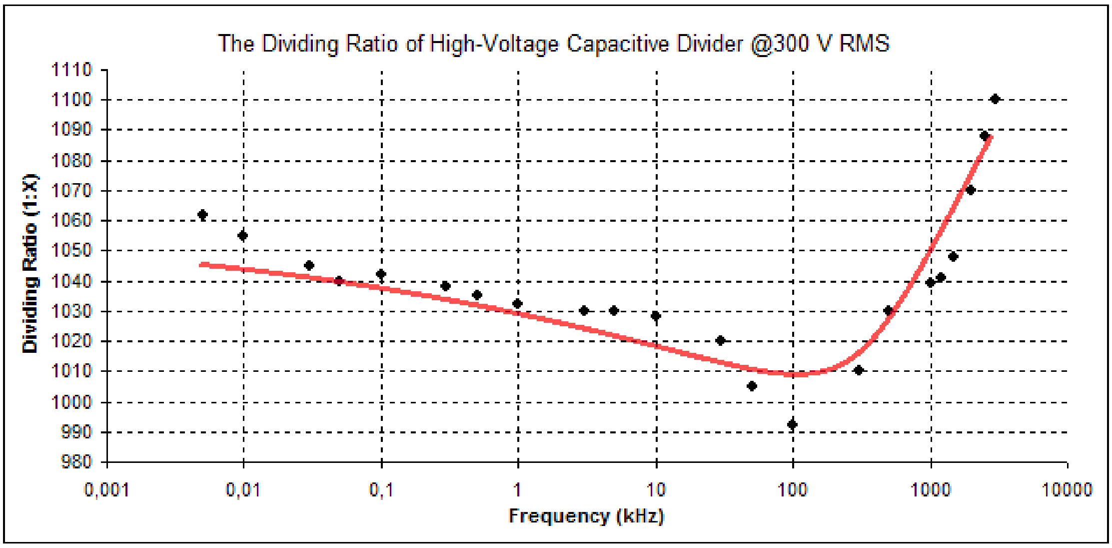

Figure 4: The dependence of the dividing ratio on the signal frequency

The values of dependence were measured at sinus input voltage of 300 VAC RMS in the frequency range from 5 Hz to 3 MHz. The measurements confirmed assumes, that divider can be used for the measuring in the frequency range from 5 Hz to 1 MHz with a maximum error of 3%.

The experimentally measured normalized atmospheric impulse 1.2/50 µs is shown in the following Figure 5. The peak value of impulse is 20 kV. The experiment demonstrates that the divider can be used for measuring the fast processes as follows.

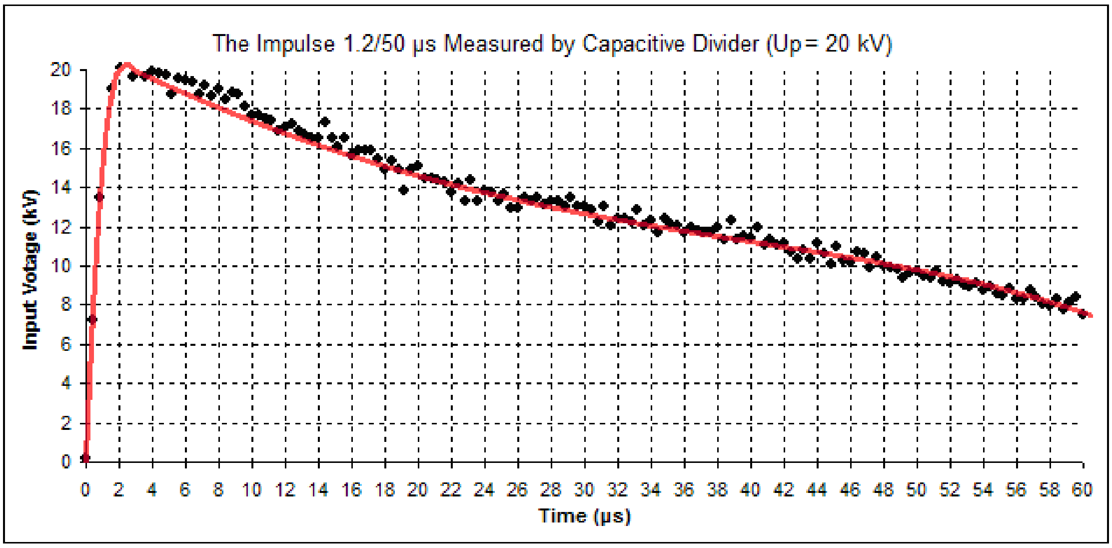

Figure 5: The measured impulse 1.2/50 µs

6. CONCLUSION

The constructed capacitive divider can be used as a simple voltage divider for measuring AC voltage to a maximum value of 120 kV/50 Hz and 80 kV/1 MHz. Moreover, the divider provides the possibility of measuring and generating a load for the continuous signal >10 kHz. The main advantage of this divider is the low cost of the individual elements and the construction, which are orders of magnitude smaller than the concurrent products.

ACKNOWLEDGEMENT

This paper contains the results of research works funded from project of specific research program of Brno University of Technology No. FEKT-S-11-19. The research was performed in Centre for Research and Utilization of Renewable Energy Sources. Authors gratefully acknowledge financial support from European Regional Development Fund under project No. CZ.1.05/2.1.00/01.0014.

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