

# Response of the grounding loop backfilled with bentonite to the lightning impulse current

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- Grounding resistance of an overhead line tower earthing electrode is one of the parameters that greatly affect the number of outages of overhead lines. In order to avoid backflashes on the overhead line insulators, which might happen during lightning strikes, the low grounding resistance for the towers' grounding loops is required (usually not over  $10 \Omega$ ). Besides, low grounding resistance ensures a proper operation of high-speed protective relaying.

- However, it is often very difficult to reach the desired grounding resistance in soils of high resistivity, as well as in soils characterized by bad contact between the grounding loop surface and the surrounding soil. This problem could be most effectively overcome by modifying the soil surrounding the grounding loop conductors using conductive backfill materials, such as bentonite

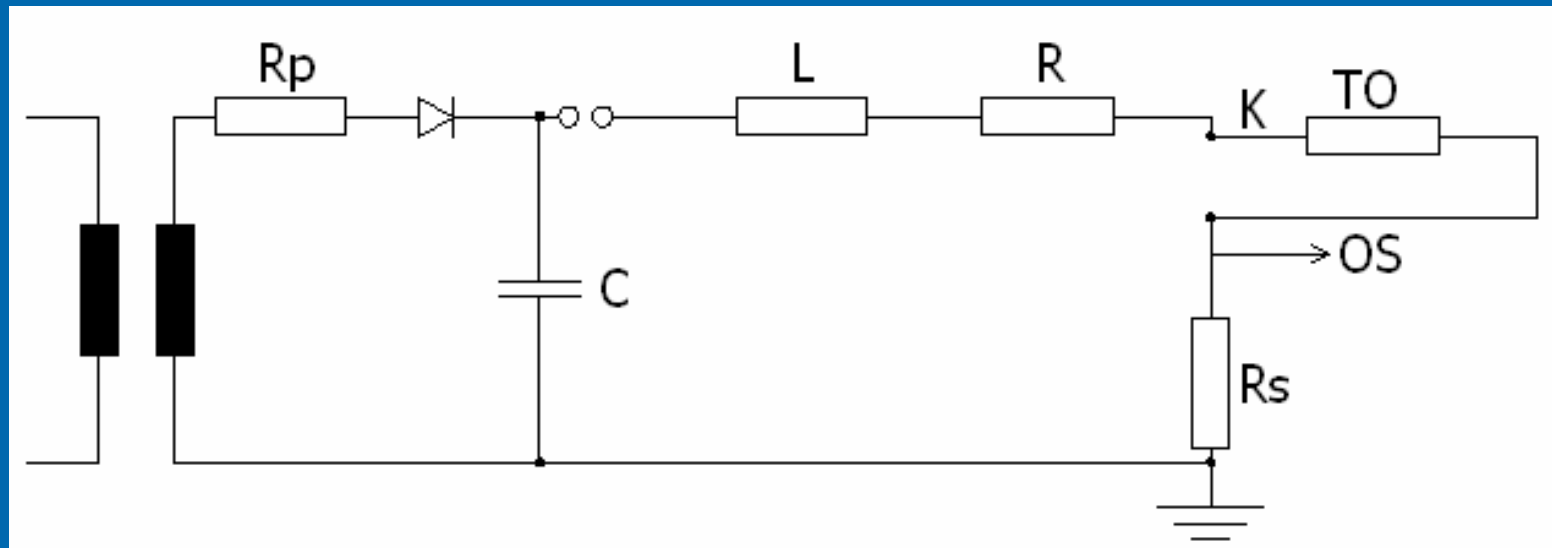
- Many positive properties of bentonite, such as very low and stable resistivity, ability to hydrate and swell (absorbing and chemically retaining water in its structure), ability to adhere to any surface, and absence of corrosive activities to zinc and iron, have been proved.

- The results of the field tests showed that the application of bentonite considerably decreases the loop grounding resistance (especially during drought periods), as well as both step and touch voltages. It was also shown that bentonite powder can be successfully used instead of bentonite suspension.

- During a field experiment in a 35 kV network, in which a grounding loop backfilled with bentonite suspension was exposed to the ground fault currents, only short-term increases of the grounding resistance were noticed.

- In order to complete the characteristics of bentonite relevant for its practical application, an experiment was carried out with a real-size grounding loop exposed to a series of lab generated lightning impulse currents.

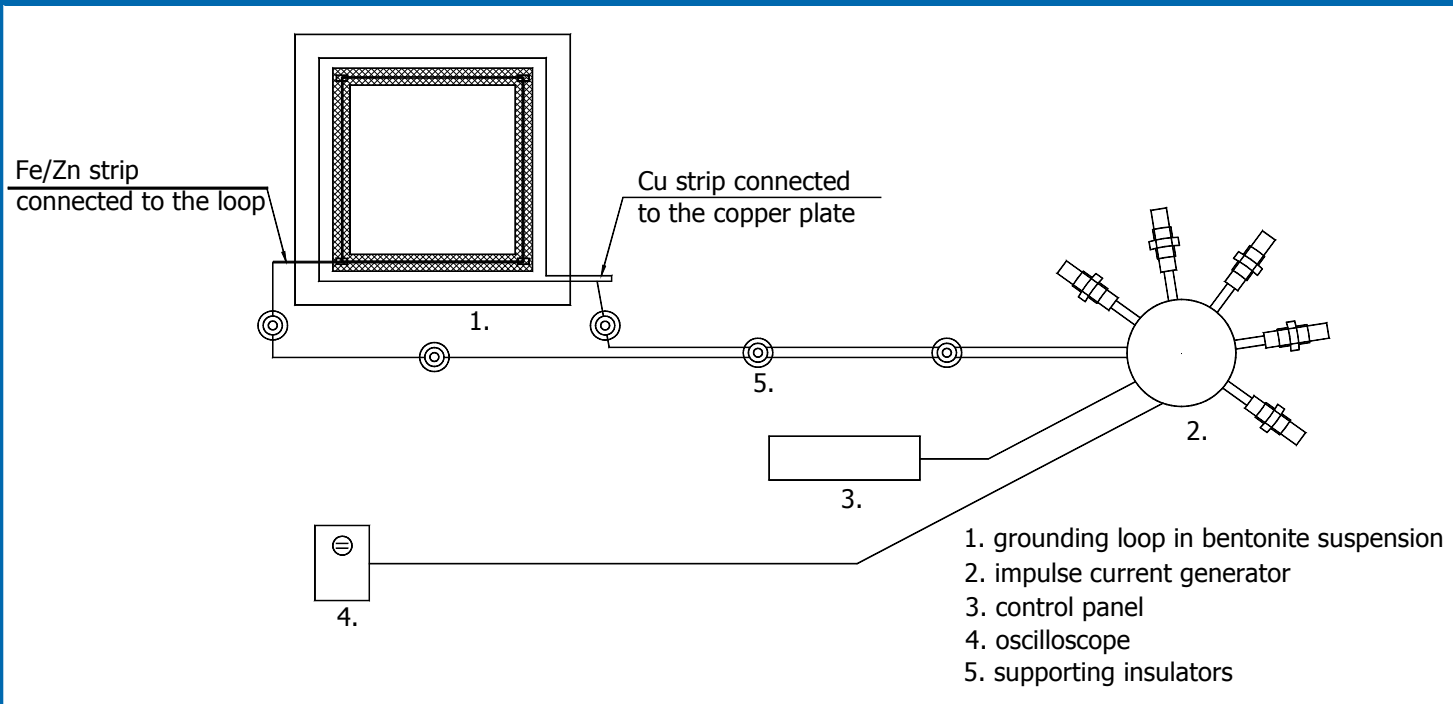
- An impulse current generator was used to simulate lightning strikes. Its parameters were adjusted to obtain the standard current waveshape 8/20. An equivalent scheme of the impulse current generator is given in the following figure.



*Equivalent scheme of the impulse current generator*



***Testing object***



***Disposal of the testing object, the impulse current generator and the measuring equipment***

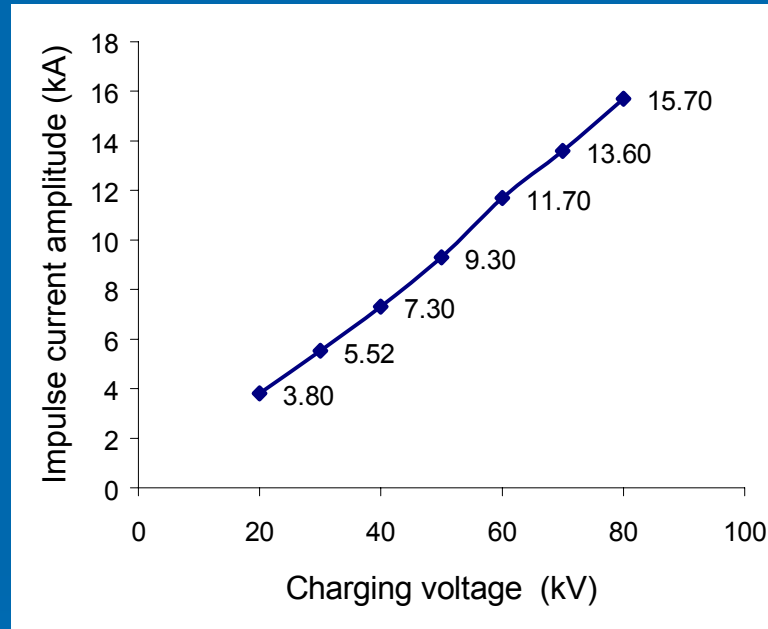
## Applied methods and measuring equipment

- The impulse current was determined by measuring the voltage at the shunt resistor of  $0.05 \Omega$  resistance. This voltage was registered by a digital oscilloscope.
- The capacitor charging voltage was measured at the control panel.
- The temperatures of bentonite, grounding strips and ambient were registered by previously installed thermal couples.

- The aim of the experiment was to check the effect of a lightning strike to the overhead line tower grounding loop backfilled with bentonite suspension. The grounding loop was exposed to lightning impulse currents of various amplitudes. The capacitor charging voltage was increased from 20 kV to 80 kV. Prior to the experiment, the loop grounding resistance of  $R=4.1 \Omega$  was measured.

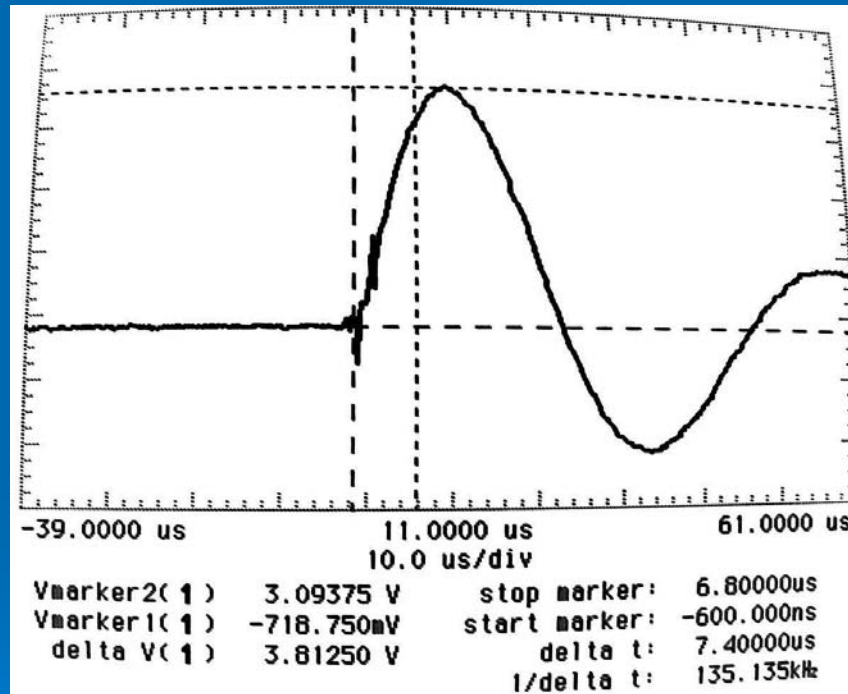
## The short-circuit test with one capacitor in the impulse current generator

- This measurement was performed in order to obtain the prospective impulse current waveform. The cables connecting the impulse current generator to the testing object formed a short-circuit (the grounding loop was not connected). It was proved that the impulse current amplitude is directly proportional to the capacitor charging voltage (as shown in the following figure).



*Prospective impulse current amplitude as a function of capacitor charging voltage*

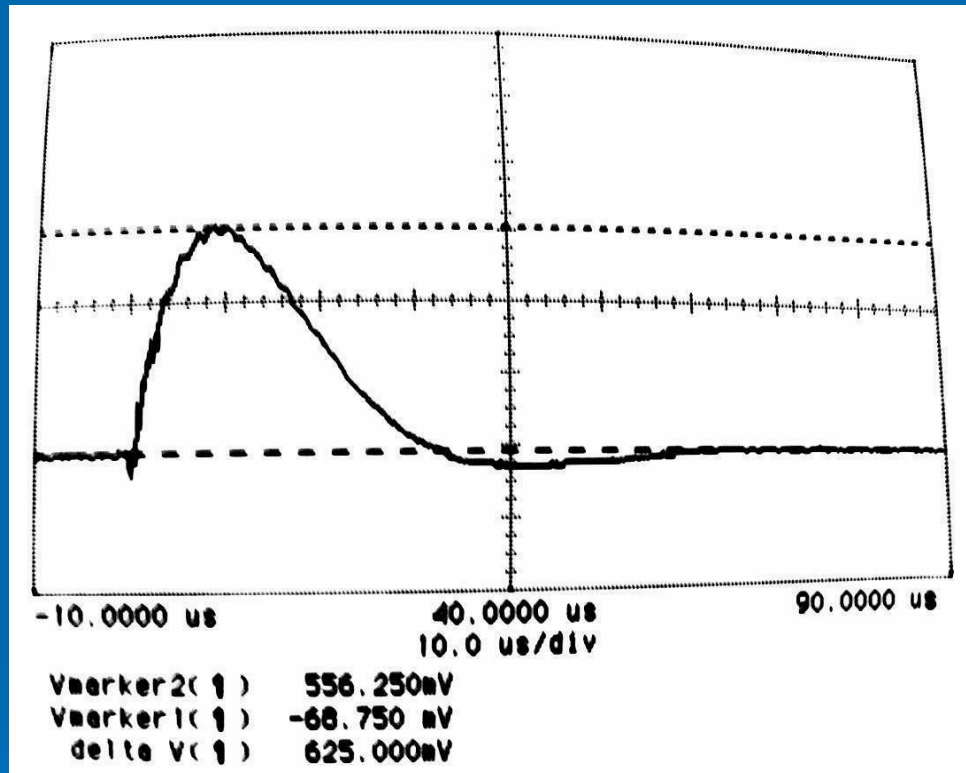
The impulse current had a sinusoidal shape:



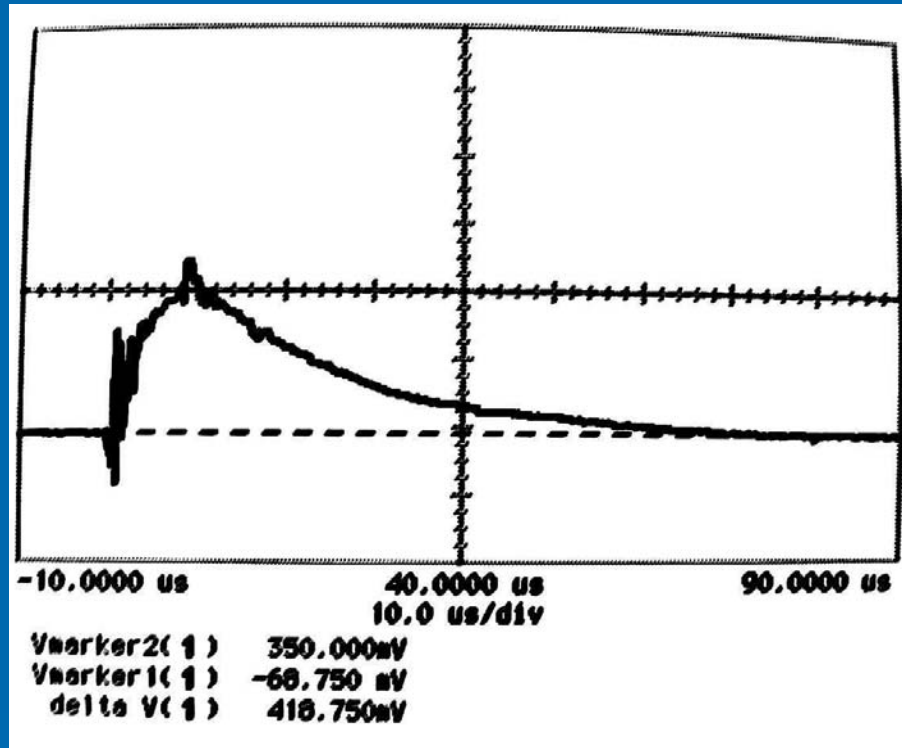
*Prospective impulse current waveform  
(charging voltage: 70 kV; impulse current amplitude:  $I_{max}=13.6$  kA)*

## Test with one capacitor in the impulse current generator injecting the impulse current into the grounding loop

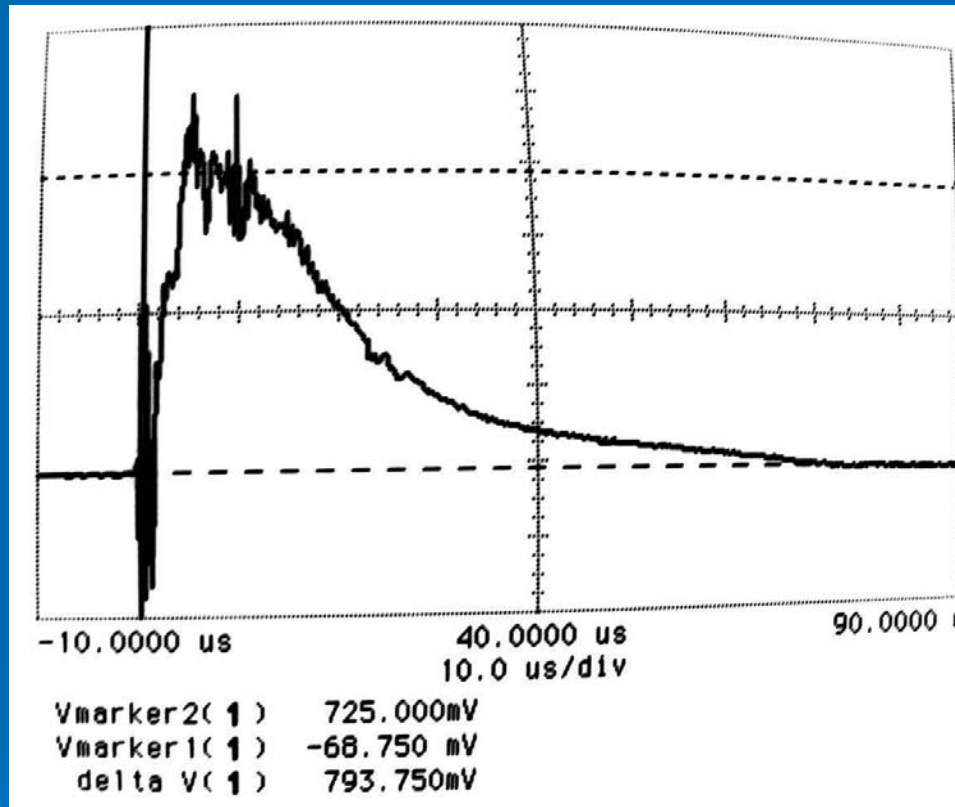
- In this test the impulse current waveforms of  $(6.3 - 8.1) \mu\text{s} / (17.8 - 21.6) \mu\text{s}$  were obtained, which comply with the standard impulse current front time and time to half-value (8/20).
- The following figures show impulse current waveforms recorded for capacitor charging voltages of 20, 30 and 70 kV.



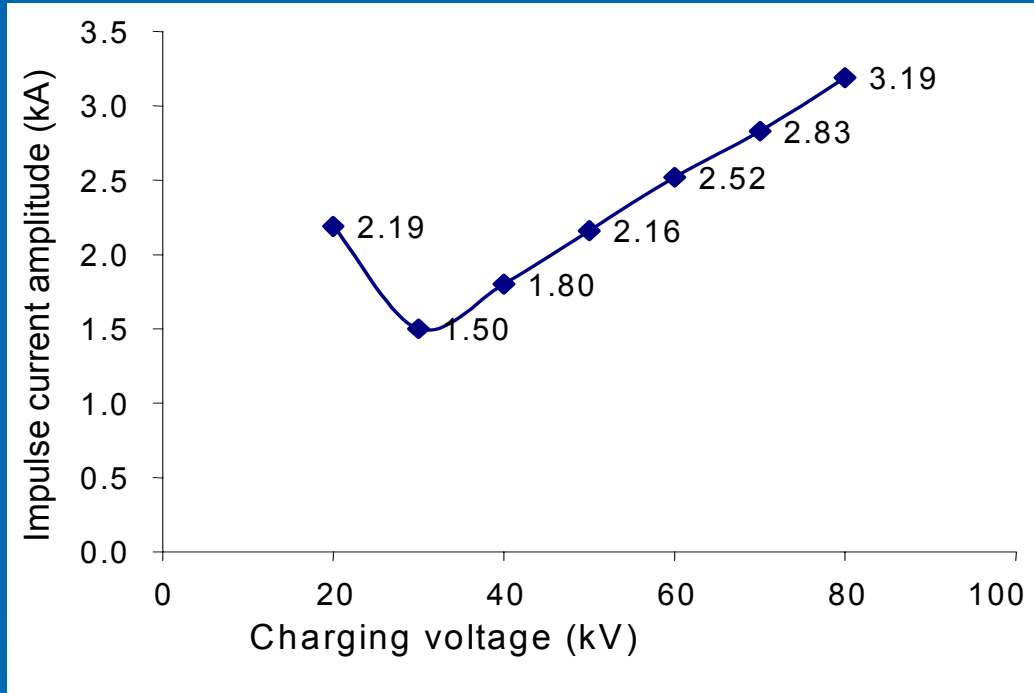
***Impulse current waveform***  
***(charging voltage: 20 kV; impulse current amplitude:  $I_{max}=2.19$  kA)***



***Impulse current waveform***  
***(charging voltage: 30 kV; impulse current amplitude:  $I_{max}=1.5$  kA)***

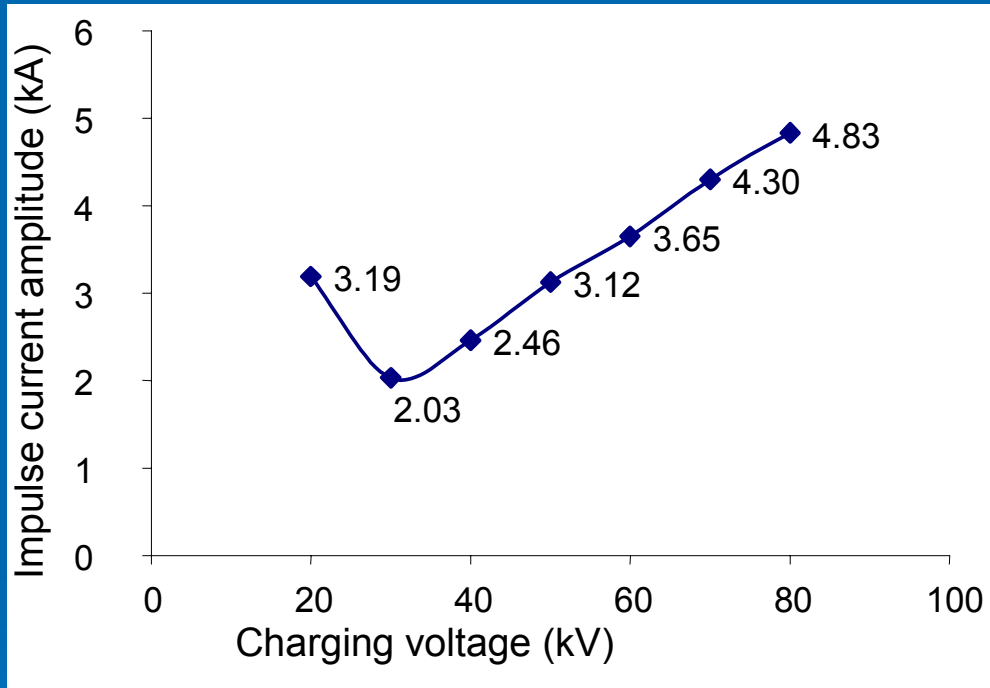


***Impulse current waveform  
(charging voltage: 70 kV; impulse current amplitude:  $I_{max}=2.83$  kA)***



*Impulse current amplitude as a function of capacitor charging voltage*

- Immediately after the first experiment with the grounding loop included into the circuit, the measured loop grounding resistance was  $R=4.1 \Omega$ , retaining the value which existed prior to the test. Also, the temperature of bentonite remained practically the same.
- Various combinations of the current injection and return points showed no practical differences in the impulse current waveshape and amplitude.



*Impulse current amplitude as a function of capacitor charging voltage  
(case with three capacitors)*

- The maximum recorded amplitude of the impulse current injected into the loop was equal to 4.83 kA. The usual 110 kV transmission line towers have four foundations, each surrounded by two grounding loops buried at different depths, size of which is similar to that of the tested one. In this case the total tower impulse current amplitude, would amount to around 38 kA, which is similar to the lightning current amplitudes appearing in nature.

# Conclusions

1. The loop grounding resistance retained the value existing prior to the test, which confirms that bentonite can be applied as backfill material for grounding electrodes of overhead line towers.

2. The following physical phenomena were noticed:

a) High-frequency oscillations in the impulse current waveform, which significantly intensify with the increase of the capacitor charging voltage. Since high-frequency oscillations do not exist if the grounding loop with bentonite is not connected, it can be concluded that the source of the high-frequency oscillations is not the cable connecting the generator and the testing object, but bentonite itself.

b) Distortion of the current waveform, changing from damped towards aperiodic oscillations with the increase of the capacitor charging voltage.