XIX-th International Conference on
Electromagnetic Disturbances

EMD 2009

September 23-25, 2009, Białystok, Poland

REMOTE EARTH LOCALIZATION FOR LIGHTNING SURGE CONDICTION ON THE HIGH VOLTAGE SUBSTATION

Jarosław WIATER
jaroslawwiater@we.pb.edu.pl
Electrical Department, Białystok Technical University, Poland

Summary: This paper presents a measurement method of adequate zero-voltage reference potential level localization for lightning surge conditions. Localization were made for the high voltage substation grounding system. All measurements were made during normal work of the real substation according a special procedure developed for this occasion. During measurements current and voltage surges were produced by the impulse generator.

Keywords: GPR, substation, lightning, remote earth

1. Introduction

Good grounding system is the most important part of the high voltage (HV) substation. There exists many factors that determines how good a grounding system is. Two major parameters are: resistance to remote earth and the resistivity of the local soil. Each of these values can be measured to help determine and design the best solution for the grounding system.

During lightning strike, grounding system will transfer lighting current to earth. Parameters of this system are changing dynamically during the lightning current flow. This effect causes a ground potential rise (GPR) during the lightning with respect to remote earth or other interconnected substation grounding system.

During the direct lightning strike to HV substation ground potential rise is strictly correlated with local soil. For proper prediction of GPR it is necessary to provide real measurements. Voltage distribution levels on the HV substation are strictly correlated to remote earth. Proper choose of it is significant for prediction accuracy and future created mathematical model verification routine.

Remote earth of the HV substation grounding system during the lightning surge conditions have got different localization then power frequency one.

This paper presents a measurement method of adequate zero-voltage reference potential level localization for lightning surge conditions on the HV substation.

2. HV substation

Measurement were provided in summer on typical Polish 110/15kV substation [1]. Analyzed HV substation consists of:

- two incoming circuits – one feeding each section of busbar and two outgoing circuits feeding multi-radial networks for overhead rural systems and ring circuits for urban cable connected networks,
- two distribution substation transformers 110/15 kV 6% 16MVA.

Fig. 1. Ground potential rise measurement process on the high voltage substation

3. Measurements

The fall-of-potential (FOP) method is typically used upon construction of an HV substation in order to validate the design calculations. The FOP method consists in essence of causing a test current to flow through the soil, from the grounding system under test to a remote current return electrode, while the resulting potential rise of the grounding system is measured with respect to a sufficiently distant potential reference electrode. Typically, several potential rise values are measured for increasingly distant reference electrode positions, in order to confirm that the full potential rise has been measured. The potential rise divided by the test current yields the ground impedance. For grounding systems that are energized by current 50Hz source FOP method is accurate, but for grounding systems energized by current surge is not [2].

First off all FOP method uses low voltage current sources, so the induced voltages can undesirable effect the results. Stray noise also becomes a greater issue. Long test leads are required for FOP. Typically HV substation grounding system is connected to lightning shield wires (or other types of ground return conductors), the effective size of the grounding system is increased for 50 Hz current energization only.

New method assumes to use surge high voltage generator as excitation. It allows to reduce significantly test leads length. Also minimize influence of connected shield wires and distance electric power system to HV substation grounding system on the measurement results. New method will be more accurate to real conditions which appears during direct lightning strike to the HV substation area.

The lightning surges were produced by the high-voltage surge generator (SG) – type UCS 500M6B. The SG covers transient and power fail requirement according to international standards with voltage capability of up 6,6kV, shape 1,2/50μs and current 3,3kA, 8/20μs. During the measurements process HV substation was working without failure. All measurements equipment was supply from gasoline generator. Listed below equipment used for measurement purposes:

- digital oscilloscope Tektronix DPO 7254, 2,5GHz, 40GS/s,
- high voltage probe with 100x attenuation. Tektronix P6009 4kV, 180MHz, input capacitance 2.5pF, input resistance 10MΩ, cable length 9ft,
- high voltage coaxial cable Zo =50Ω,
- oil generator.

Figure 2 is a functional block diagram of the equipment used for the ground potential rise measurements – a surge generator and digital oscilloscope. As shown in

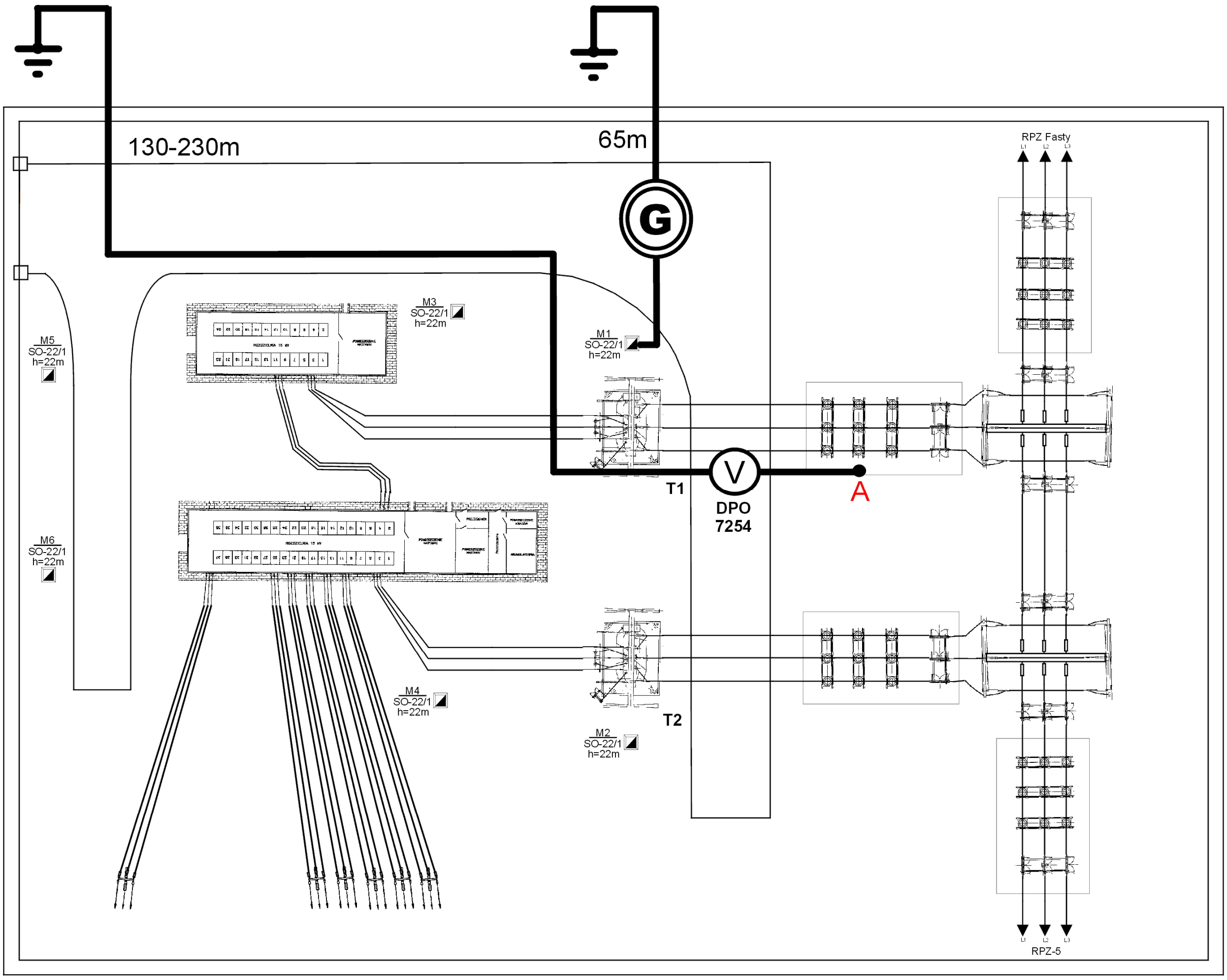


Fig. 2. Functional block diagram of the equipment used for GPR measurements

Figure 2, a current 126 A, 9/70µs was injected from a surge generator between the substation's lightning rod and a remote additional current return electrode – figure 3.

Additional test grounding system (voltage one) were located with variable distance (from 130m to 230m) to HV substation grounding system – fig. 2. Potential rise values were measured for different distant reference electrode positions, in order to confirm that the maximal potential rise has been measured. A digital scope measured the potential difference between two points. First one were constantly connected to grounded circuit breaker in T1 transformer measurement section and the first additional test grounding system. In this way a remote earth were found. Next additional test grounding system (current one) were made for current circuit. A length and distance from HV substation for current circuit were constant. On figure 4 some measurements results were presented for two different distance from HV grounding system. Apparent differences appears in peak value. Shape of two presented waveforms were distorted by wave phenomenon which appears in few hundred meters length cable. Waveforms were little bit shifted by wave phenomenon. It could be also caused by wave reflection from the end of remote ground wire.

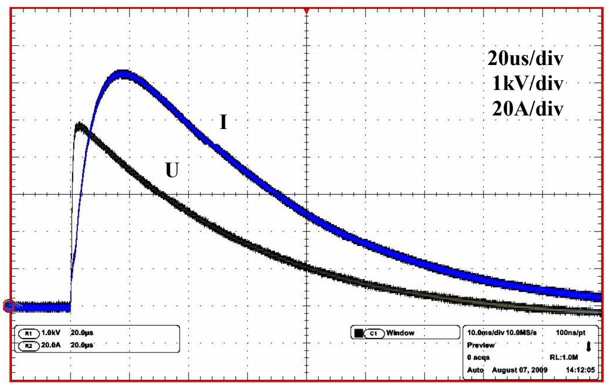
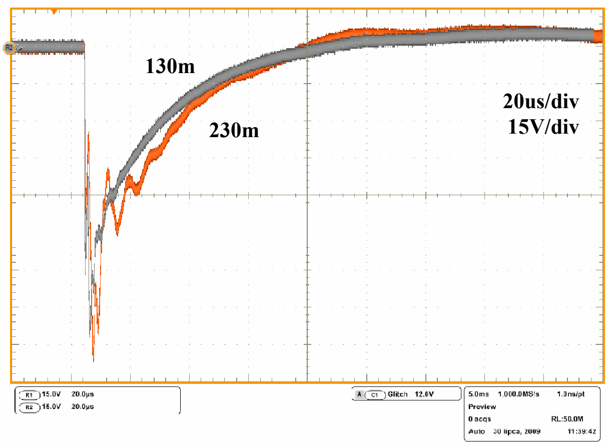


Fig. 3. Voltage and current on the surge generator output (black curve – U_{max}=5kV, blue one – I_{max}=126A)

a)



b)

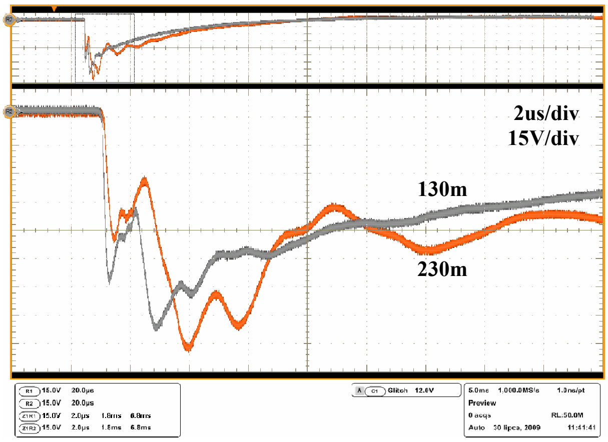


Fig. 4. Ground potential rise on the high voltage substation grounded circuit breaker in T1 transformer measurement section (grey curve – voltage test leads length 130m, orange curve – voltage test lead length 230m), a) t∈<0;200>µs; b) t∈<0;20>µs

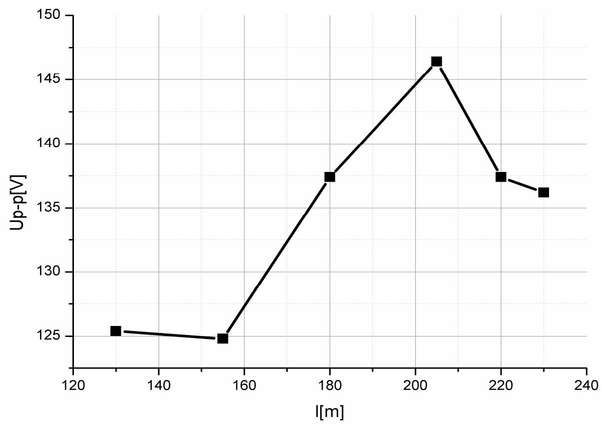


Fig. 5. Ground potential rise on the high voltage substation for different voltage test leads length

Detailed measurements shows that remote earth in analyzed HV substation is located 205 meters from HV substation – fig. 5. It is large difference in compare to the results obtained by FOP method. Difference is crucial for surge conditions which appears during direct lightning strike on the HV substation area.

4. Conclusions

Direct lightning strike to the earthed components of HV substation can cause severe interference problems in electronic equipment and systems. In article were presented new method of remote earth localization for surge conditions especially lightning. Measurements results also shows that large grounding system connected by shield wires to the HV substation haven't produce reduction impact on GPR during lightning strike.

5. References

1. PN-E-05115, Power installations exceeding 1kV a.c., p.78.
2. Ses Software Canada, HIFREQ Theory.