TECHNICAL UNIVERSITY – SOFIA
Department Theoretical Electrical Engineering

10TH SUMMER SCHOOL

ADVANCED ASPECTS OF THEORETICAL ELECTRICAL ENGINEERING

Sozopol'14

PROCEEDINGS

Edited by: Valeri Mladenov
Snejana Terzieva

in the framework of

DAYS OF SCIENCE
OF THE TECHNICAL UNIVERSITY OF SOFIA

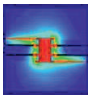
Sozopol'14, BULGARIA, 19-22.IX.2014

ORGANIZATION

The Summer School is organized by the Department of Theoretical Electrical Engineering at the Technical University of Sofia in the framework of the "Days of Science of the Technical University of Sofia", Sozopol, Bulgaria, September 2014

TECHNICAL UNIVERSITY OF SOFIA, BULGARIA

under the patronage of the INTERNATIONAL SYMPOSIUM ON THEORETICAL ELECTRICAL ENGINEERING (ISTET) and it is a regular ISTET event



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DEPARTMENT THEORETICAL ELECTRICAL ENGINEERING

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Edited by: **Valeri Mladenov**
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PREFACE

These Proceedings contains the plenary lectures and the regular papers presented at the *10th* Summer School *Sozopol'14*, which took place in Sozopol, Bulgaria, between *19* and *22 Sept*. 2014 in the framework of the "Days of the Science of the Technical University of Sofia". The Summer School covers the advanced aspects of Theoretical Electrical Engineering and it is a platform for postgraduate training of Ph.D. students and young scientists. During the Summer School well-known experts presented some advanced aspects of circuits and systems theory, electromagnetic field theory and their applications. Apart from the educational part of the Summer School a presentation of original authors' papers took place.

The main topics of the Summer School *Sozopol'14* include Circuits and Systems Theory and Applications, Signal Processing and Identification Aspects, Electromagnetic Fields, Theoretical Concepts, Applications and New Approaches in Educating Theoretical Electrical Engineering. The Summer School *Sozopol'14* has been organized by the Department of Theoretical Electrical Engineering of the Technical University of Sofia with the main sponsorship of the Research and Development Sector of the Technical University of Sofia.

This has been the tenth edition of the event, after the Summer Schools in 1986, 1988, 2001, 2002, 2005, 2007, 2009, 2010 and 2012. The Summer School is under the patronage of the International Symposium on Theoretical Electrical Engineering (ISTET) and it is a regular ISTET event. There were 35 participants at the Summer School this year. There were 6 plenary lectures and 23 regular papers that are published in these Proceedings. Providing the recent advances in Theoretical Electrical Engineering the Proceedings will be of interest to all researchers, educators and Ph.D students in the area of Electrical Engineering.

Special thanks are due to the Research and Development Sector, Faculty of Automation and the Section of Social Services of the Technical University of Sofia about the overall support of the event. We also would like to thank to the IEEE Bulgaria CAS Chapter and the World Scientific and Engineering Academy and Society (WSEAS), which also partially sponsored the event. We hope to meet again in the following edition of the Summer School to continue the good tradition and collaboration in the field of Theoretical Electrical Engineering.

Organizing Committee
Sofia, October 2014

CONTENTS

SECTION 3 – ELECTROMAGNETIC FIELDS, NEW APPROACHES IN EDUCATING THEORETICAL EE

MODELING OF THE ELECTRICAL DISCHARGE OF LIGHTING ON OVERHEAD POWER LINE

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Abstract. *The electrical discharge of lightning, which strikes down the wires of overhead power line for high voltage – 110 kV is investigated. Electrostatic discharge model of lightning is created. Simulations of emergency mode of the power line in the case of direct hit of lightning are made. The harmonic composition of the current of lightning discharge is investigated. The electrical discharge of the lightning creates a high voltage level of the power line. These surges and the availability of harmonic currents violate electromagnetic compatibility. They create disturbing effects of the overhead power line for high voltage and other electrical equipment in the vicinity.*

Keywords: *electrostatic discharge, overhead line, high-voltage, modelling, SPICE simulation, electromagnetic compatibility*

1. INTRODUCTION

The lightning is an eternal source of charge of Earth electric field. Source of lightning are electric charges of the storm clouds. At any time, at different points of the Earth's lightning flashes over 2,000 thunderstorms. In every second of about 50 lightning strikes the surface of the earth, and on average, each square kilometre of its lightning strikes six times per year. More Benjamin Franklin showed that lightning hitting on the ground from the storm clouds - are electrical discharges that carry a negative charge on it.

Formation of storm clouds according to the modern theory of thunderstorms is done in the following way. In an atmosphere of saturated steam under the influence of a strong air flow occurs spray of water droplets. The received as a result of spray water mist is loaded with negative charges, and the remaining drops with positive charges.

Lightning - greetings from the space, and X-ray source. However cloud unable itself so electrify itself to cause a discharge between its lower part and ground. The electric field in the thundercloud never exceeds 400 kV/m, and the electric breakdown in air occurs when the tension more 2500 kV/m. Therefore for the occurrence of lightning need something else other than the electric field. In 1992 Russian scientist Alexander Gurevich of Physics Institute Lebedev (LPI RAS) has suggested that a

kind of lightning-ignition may be cosmic rays- high energy particles raining down on Earth from space at nearly the light speed [7].

2. LIGHTNING ELECTROMAGNETIC PULSE

The current of the lightning has the shape of a pulse shown in Fig. 1 [8] and is characterized by three parameters:

- I_m is amplitude of the lightning current;
- $\tau_в$ is wavelength;
- $\tau_ф$ is length of the front
- $\alpha = \frac{I_m}{\tau_ф}$ is average steepness of the current.

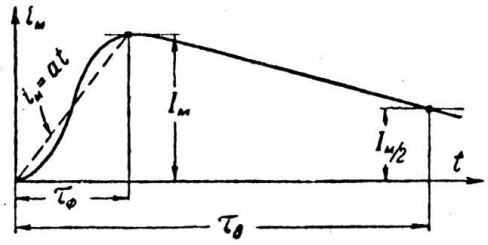

Fig. 1. Electromagnetic wave form of lightning current

The amplitude value of the current is 20kA up to 200 kA. The steepness of the wave front of the current is about 300 kA / μs. The electric field intensity in the cloud is about $E_0 \approx 10^4 V/m$. At certain points the electric field intensity can reach 1 MV/m ÷ 3 MV/m.

3. MODELING OF THE LIGHTNING CURRENT

Circuit model of the lightning current is created. The software package PSpice (ORCAD) [9] is used. The lightning current is represented by a piece-wise linear current source.

The shape of the lightning current has the form shown in Figure 2.

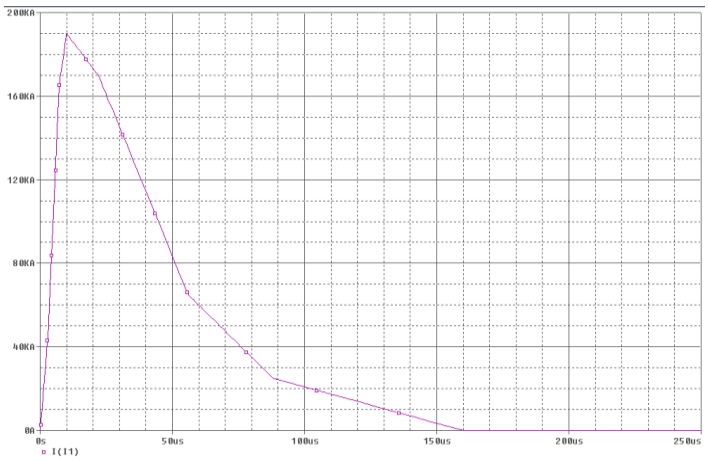

Fig. 2. The shape of the lightning current model

4. MODEL OF THE ELECTRIC DISCHARGE OF LIGHTNING ON THE POWER LINE

A lightning strike on the final stretch of overhead high voltage power line 110 kV is considered. The electrical discharge of lightning strike on the power line wires is investigated.

Circuit model of overhead power line 110 kV, presented with concentrated parameters is used [10].

A model of electrostatic discharge lightning is created.

The SPICE model of the lightning discharge on overhead power line110 kV is shown in Fig. 3.

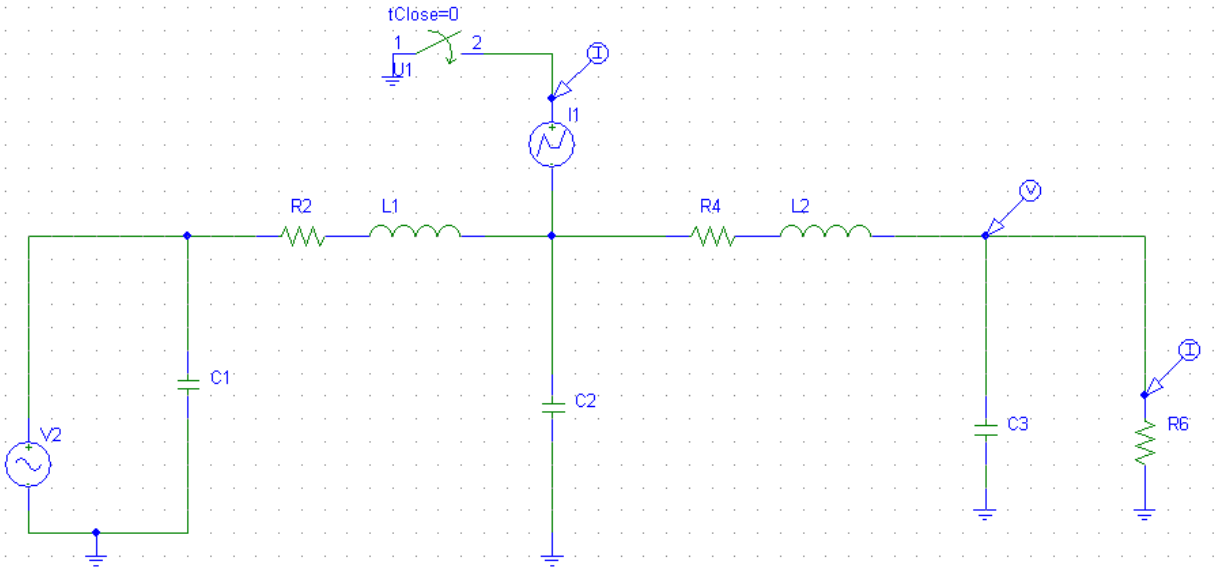

Fig. 3. Model of the lightning discharge in power line for HV

5. SIMULATIONS REZULTS

Simulations are carried on the work of the power in emergency mode at discharge in the power of lightning. The power line is supplied from a voltage source 110 kV from the nearest substation is loaded with load lowering substation 110/20 kV.

When lightning strikes occurs emergency mode in which the voltages and the currents in the power line significantly exceed the nominal values.

The results of the simulations of discharge through the power line of the bolt shown in Fig. 4 and Fig. 5.

The voltage on the 110 kV power line even for a very short time reaches too high values of the order of several MB. These surges can disrupt the normal operation of the power line, due to the appearance short-earth compounds. As a result will be reduced the operation resource of the insulation.

In terms of electromagnetic compatibility for other electrical equipment located in vicinity, the power line can creates surges, which can create dangerous levels of electric intensity and disrupt their normal operation. As a consequence, the radio-

electronic equipment will create harmful interference, which will briefly interrupt its work.

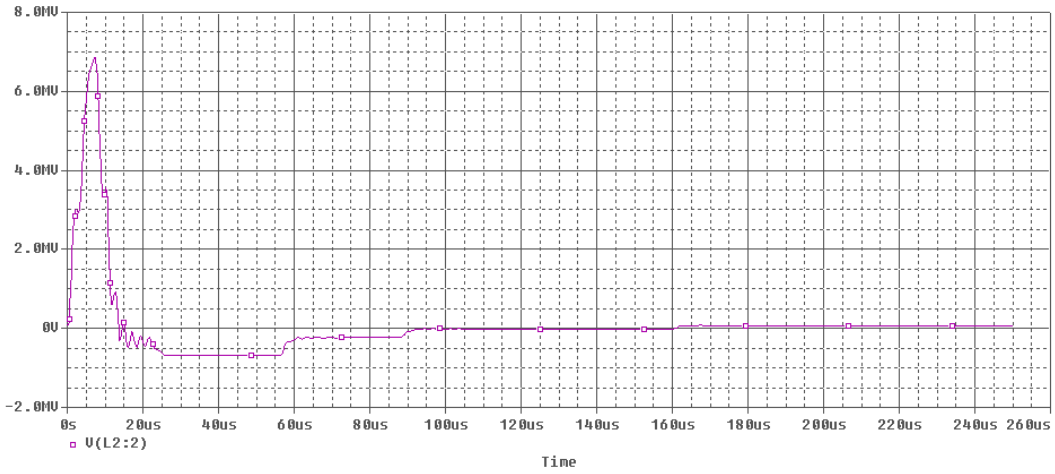

Fig. 4. Surge of lightning discharges on the 110 kV power line

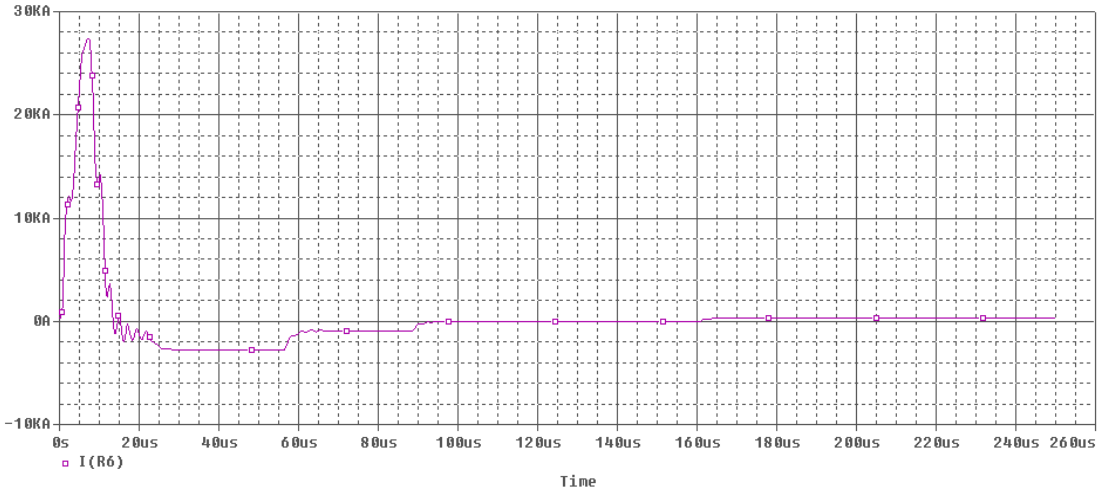

Fig. 5. Electricity lightning current in 110 kV power line

The induced overcurrents from the lightning of range of several kA can disrupt the normal operation of the power line. They can increase the power losses and voltage in the power line wires 110kV Albeit for a short time they will be given a large amount of energy. This affects the performance of power line.

These large currents, even for a short time will create strong magnetic fields around 110 kV power line. This will also lead to distortions of normal operation of other electrical equipment around the power lines.

6. CONCLUSION

The electrical discharge of lightning striking on overhead power high voltage 110 kV is investigated.

A model of current electrostatic discharge of lightning is created.

Circuit model of the power line of high voltage in a lightning strike is composed.

Simulations are carried on the work of the power line in emergency mode in the case of discharge of lightning in the power line.

Electrical discharge of lightning creates a high voltage in the power line. These surges and the presence of harmonic currents violate the electromagnetic compatibility of high voltage power lines and other electrical equipment located in the vicinity of lightning strikes on power lines.

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