10th Eco-Energy and Materials Science and Engineering Symposium


On December 5-8, 2012
Sunee grand hotel,
Ubon-ratchathani

Organized by

Co-organized by
PREFACE:
Message from the President of
Rajamangala University of Technology Thanyaburi

Rajamangala University of Technology Thanyaburi (RMUTT), in conjunction with Kyoto University, is pleased to host the 10th Eco-Energy and Materials Science and Engineering Symposium (10th EMSES). This international conference is not only giving an opportunity for Thai and foreign researchers to present and discuss their research works and update their expertise but also to initially stimulate the development of research works on eco-energy and materials science and engineering. Our program consists of six research tasks: (1) Energy Technology, (2) Environmental and Social Impact, (3) Nanotechnology and Materials Science, (4) Energy Economics and Management, (5) New Energy technology and (6) Nuclear Technology.

I would like to take this opportunity to express our sincere gratitude to our two distinguished Plenary Speakers for kindly accepting our invitation. I deeply appreciate of the very strong support given by Kyoto University. Thanks to the tireless works of the Organizing Committee, the Technical Program Committee, the invited speakers and paper and poster contributors, and excellent program been assembled to cover a broad spectrum of interesting topic.

We warmly welcome you to the 10th EMSES on December 5-8, 2012, Ubon Ratchathani, Thailand.

Numyoot SONGTHANAPITAK, Ph.D.
President of Rajamangala University of Technology Thanyaburi
and Conference Chairman of 10th EMSES 2012
PREFACE:
Message from the Director of
Institute of Advanced Energy, Kyoto University

It is my great pleasure to have the 10th Eco-Energy and Materials Science and Engineering Symposium (EMSES) with Rajamangala University of Technology Thanyaburi (RMUTT) under the long-term collaboration between RMUTT and Kyoto University. The 1st EMSES was held in 2001 in Thailand and the symposium has been expanded in its scientific contents as well as the academic network. I believe that the 10th EMSES gives a good opportunity to all participants to exchange their knowledge and idea to realize eco-friendly energy system in society. I would like to express my welcome to all participants and sincere thanks to the 10th EMSES organizing committee and all supporting organizations to make us having this symposium.
I hope that the symposium will be successful and lead to further progress in energy science and technology and also in friendships of participants.

Yukio Ogata, Ph.D.
Director of Institute of Advanced Energy, Kyoto University
PREFACE:
Message from the Former Dean of
Graduate School of Energy Science, Kyoto University
Program Leader,
Global COE “Energy Science in the Age of Global Warming”

I want to express my hearty welcome to all participants of Eco-Energy and Materials Science and Engineering Symposium (10th EMSES). This symposium is aiming the realization of importance of energy and materials technology through the academic, science and technology network among the world communities. The symposium gives an opportunity for researchers to discuss their research works and also to initially stimulate the development of research works on eco-energy and materials science and engineering. Once the cooperation among researchers has been created, the further cooperation work will be developed.

I would like also extend my sincere thanks to all who made the meeting possible, including the 10th EMSES organizers, the SEE forum committee members, and the Japanese Government, JSPS, for their kind support. I am looking forward to seeing you in Ubon Ratchathani, Thailand.

Professor Takeshi YAO, Ph.D.
Former Dean of Graduate School of Energy Science, Kyoto University
and Program Leader, Global COE “Energy Science in the Age of Global Warming”
Message from the Chairperson of 10th EMSES Organizing Committee

Rajamangala University of Technology Thanyaburi (RMUTT), in conjunction with Kyoto University, is pleased to host the 10th Eco-Energy and Materials Science and Engineering Symposium (10th EMSES).

RMUTT has a major mission on encouraging and supporting all areas of research. One of the key reasons is to assist in developing capability in science and technology in order to cope with recent rapid change in this field. We have jointly set up an academic symposium on the 10th EMSES with the perception on the significance of exchanging knowledge and research experiences between researcher in the field of energy, materials technology and environmental science. This symposium is not only giving an opportunity for Thai and foreign researcher to present and discussion their research works and update their expertise but also to initially stimulate the development of research works on eco-energy and materials science and engineering. Once the cooperation among researchers has been created, the closer future cooperation incorporate with joint-research works will be developed. Thus, to support the aforesaid role, the symposium working committee would like to invite you to participate in this academic symposium.

I would like to express our sincere thanks to the organizing committee, participants and contributors for your kind corporation to this symposium. I wish this symposium proceeding will be a useful reference for future scientific research development.

Sommai PIVSA-ART, Ph.D.
Dean of Faculty of Engineering, RMUTT
Director of CoE on Sustainable Energy System (Thai-Japan)
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30° x100 = 3000
## Conference Program of 10th Eco-Energy and Materials Science and Engineering

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<tr>
<td>07:00-09:00 am</td>
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| 09:00-09:40 am   | Opening Ceremony at Taptim Siam 4 Hall  
|                  | Assoc. Prof. Dr. Numyoot Songthanapitak, President of RMUTT, Thailand and Chairperson of 10th EMSES conference  
|                  | Prof. Dr. Kiyoshi Yoshikawa, Vice President of Kyoto University, Japan Co-Chairperson of 10th EMSES conference  |
| 09:45-10:45 am   | Keynote Speaker I: Japan Power Generation Mix and Energy Security after Fukushima Nuclear Accident, presented by Professor Dr. Keiichi N. Ishihara, Graduate School of Energy Science, Kyoto University, Japan |
| 10:45-11:00 am   | Coffee break              |
| 11:00-12:00 am   | Keynote Speaker II: Vertical Motions in Greater Bangkok Area after the 2004 Sumatra-Andaman Earthquake from GPS Observations and Its Prediction based on the Geophysical Modelling, presented by Professor Dr. Chalermchon Satirapod, Chulalongkorn University, Thailand |
| 12:00-01:30 am   | Lunch at Taptim Siam 5 Hall |

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<td>01:30-03:00 pm</td>
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<td>Chair</td>
<td>Prof. Dr. Paungsaik Rafthanachio</td>
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<td>Co-Chair</td>
<td>Dr. Wirachai Roynarin</td>
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<td>Dr. Sorapong Pavadupree and Dr. Sumonman Niamlang</td>
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<td>Dr. Seichi Aiba</td>
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<td>Dr. Supaporn Tomson</td>
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<td>Assoc. Prof. Dr. Nari Charoenvai</td>
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<td>Assoc. Prof. Dr. Nari Charoenvai</td>
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<td>03:15-04:00 pm</td>
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<td>Prof. Dr. Chul-Su Kim</td>
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Analysis of Lightning Phenomena for Underground Petroleum Pipeline System

B. Topradith, K. Bhumkittipich and T. Suwanasri

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2Power System and Energy Research Center, Department of Electrical Engineering, Faculty of Engineering, Rajamangala University of Technology Thanyaburi, Klong 6, Thanyaburi, Pathumthani 12110
3The Sirindhorn International Thai-German Graduate School of Engineering (TGGS) in North Bangkok, Thailand
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Abstract—This paper presents the lightning phenomena analysis for underground petroleum pipeline system and protection guideline by considering an electrical continuity after a lightning strike to the earth. The result of transient state occur on the pipeline by using mathematical program (ATP-EMTP) to simulate standard waveform 10/350 micro second which will be linked to several dimensions. This study will transform physical characteristics into electrical characteristics such as pipe metal, pipe insulator, conductors in corrosion protection circuit and earth as parameters in the analysis. The result of this simulation found that the transient voltage will rise higher if length is longer and higher than safety allowance of pipe corrosion protection equipment. To limit this over voltage, this study used proper lightning protection equipment characteristics. From the result of simulation and the proper characteristics of lightning protection equipment, the transient voltage was limited follow BS 60950 standard. The result showed that the correct lightning protection equipment will help to reduce damage to asset of petroleum transportation industry from lightning strike.

Keywords—Pipeline, Lightning, Impedance, Transient, Induced voltage.

1. INTRODUCTION
Pipeline Petroleum transportation is the fastest, convenience and safety. Its energy per unit cost is lowest when compare to other transportations. Normally underground petroleum pipeline will be laid at approximately 1.5 meter depth from soil surface and parallel to railway or high voltage transmission line. From the record found corrosion protection devices which connect to pipeline always damage from lightning. [1]

The previous studies on the effect of lightning to pipeline and how to protect pipeline coating, was on natural gas pipeline which laid nearby high structure and used finite element method [2] and CDEGS [3] program not only to study in electrical induction through pipeline which laid above soil and underground but also the possibility of underground cable damage from lightning at 132 kV. [4] Those studies did not consider about the combined of pipeline impedance and corrosion protection device cable impedance.

This article presents lightning phenomenon analysis for underground petroleum pipeline and its protection methodology by using program which used to simulate transient state in power system by considering both petroleum pipeline impedance and corrosion protection device cable impedance.

2. Lightning phenomenon analysis
From standard IEC 61312 – 1, the maximum lightning current is 200 kA with 10 / 350 micro second waveform. As shown in figure 1, when lightning struck to construction, 50% of lightning power will be dissipated to earth, the left will be dissipated to other systems in the building that can be interfered such as power system, telephone cable or communication system.

From statistical number of lightning magnitude in Thailand at 20 kA [5], the dissipation to earth current will be dissipated to underground petroleum pipeline.

2.1 Lightning waveform function
Lightning current is the most important factor in lightning phenomenon analysis for underground petroleum pipeline. Current function is a time domain function which can use Heidler's mathmatic function to analyze its waveform [6] as following equation (1) – (4) which comply to IEC-61312-1

\[ i(t) = I_0 \cdot x(t) \cdot y(t) \]

\[ x(t) = \text{Power function} \]
\[ y(t) = \text{Exponential Function} \]

\[ x(t) = \frac{K^2}{(1 + K_1^2)} ; K_1 = \frac{t}{\tau_1} \]
\[ y(t) = \exp(-\frac{t}{\tau_1}) \]

\[ i(t) = \frac{I_0}{h} \cdot \frac{(t/\tau_2)^n}{1 + (t/\tau_2)^n} \cdot \exp\left(-\frac{t}{\tau_2}\right) \]

\[ i(t) \] is lightning current, \( I_0 \) is peak current, \( h \) is coefficient to correct peak current, \( t \) is time, \( \tau_1 \) is front time constant, \( \tau_2 \) is tail time constant, \( n \) is slope factor

2.2 Lightning waveform
From IEC 61312-1 standard as shown in figure 2, the lightning waveform which T1 is front wave time constant and T2 is tail wave time constant. T2 is considered at 50% peak current. The ratio of current to time is called steepness. \( \frac{di}{dt} \), its unit is \( \text{kA/s} \).

![Fig. 2 Lightning current waveform](image)

### 2.3 Pipeline system impedance

This analysis does not concern about lightning frequency so pipeline impedance per unit is calculated by using Laplace Transform by Resistance = \( R \), Inductance = \( sL \), Capacitance = \( 1/sC \).

### 2.4 Step voltage

As shown in figure 3, after lightning current reach the ground this position will contain maximum intensity of electrical field. This will cause lightning current and potential dissipate along soil surface in circular. The distance between each circular is approximately the same length as human step. We call this electrical circular as step voltage. In case petroleum pipeline and corrosion protection device cable are in the way of lightning current dissipation and step voltage, by through soil resistance through pipeline insulation and to pipeline metal, petroleum pipeline will get an effect by lightning current and step voltage too. The calculation of lightning current and potential are shown in equation (5)-(6)

\[
\Delta V = \frac{l \rho}{2\pi} \left( \frac{s}{d(d+s)} \right)
\]

\[
I_s = \Delta V / R
\]

\( \Delta V \) is step voltage, \( \rho \) is specific soil resistance, \( I \) is lightning current, \( s \) is step distance, \( d \) is distance away from lightning first reach ground, \( R \) is soil resistance per meter, \( I_s \) is step current.

![Fig. 3 Underground pipeline in the radius of step voltage](image)

The distance away from lightning point to pipeline through step voltage for 5 meters, its current and potential will decrease. The lightning current at pipeline surface can be calculated as in equation (6) this current will be used as a parameter for lightning current sourcing in program ATP-EMTP.

### 2.5 Induced voltage from pipeline induction

When lightning current reach the ground, the electrical continuity which includes soil, pipeline insulation, pipeline metal and electrical cable will cause induced voltage along pipeline which is shown as in equation (7)

\[
V_{pip} = L_{pip} \frac{di}{dt}
\]

\( V_{pip} \) is induced voltage at pipeline, \( L_{pip} \) is induction coefficient per 1 meter length, \( \frac{di}{dt} \) is the rate of change of lightning appeared at pipe per time which can be calculated from equation (8) which is derived from equation (4)

\[
\frac{di}{dt} = \frac{l_0}{h} \left[ \left( \frac{t/t_1}{t/t_1 + 1} \right)^{10} \exp(-t/t_2) + \exp(-t/t_3) \right] \left( 10(t/t_1)^{10} + 10(t/t_1)^{20} \right) \left( 1 + (t/t_1)^{10} \right)^{-1} \left( 1 + (t/t_1)^{20} \right)^{-1}
\]

### 3. Electrical characteristic of soil, pipeline insulation and pipeline

#### 3.1 Electrical characteristic of soil

Many researches have stated about electrical characteristic of soil because it has both direct and indirect contact to pipeline system on its electrical continuity. From figure 4, when consider electrical characteristic of soil there are compose with resistance (R) 1000 Ohm/m and capacitance (C) 221.35 pF/m as shown its equivalence circuit

![Fig. 4 Soil equivalent circuit](image)

#### 3.2 Electrical characteristic of pipeline insulation

External coating by using Fusion Bonded Epoxy (FBE) to protect directly contact between pipelines and soil, this will help to protect corrosion by its characteristic that withstand corrosion via acid or base and other corrode solutions and also has a very high resistance. When considering its characteristic it compose with resistance and capacitance by its resistance (R) 3.33\( \Omega \)/m as follow ASTM-D257 and its average capacitance (C) 10.42 pF/cm\(^2\) from field measurement.

#### 3.3 Electrical characteristic of underground pipeline

Petroleum pipeline material comes from metal so when we consider its electrical characteristic it will compose with resistance per length (R) and its induction per length (L) as well. Normally its resistance is around...
56.941 941 μΩ/m [8] and its average induction is around 0.495 μH/m. Those values come from field measurement on 14" diameter pipeline.

Fig.5 Electrical element of pipeline

3.4 Surge protection
Metal oxide surge protection normally has a very high resistance and inverse to potential. Its current and potential characteristic are as in Table 1 and its approximately calculation value as equation (9)

Table 1. V/I characteristic of arrester

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<th>V</th>
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<th>520</th>
<th>600</th>
<th>680</th>
<th>780</th>
<th>950</th>
<th>1.5k</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>10^4</td>
<td>10^5</td>
<td>10^6</td>
<td>10^7</td>
<td>10^8</td>
<td>10^9</td>
<td>10^10</td>
<td>10^11</td>
<td>10^12</td>
</tr>
</tbody>
</table>

\[ I = kV^n \]  

(9)

I is current pass through surge protection device, k is constant value depend on type of surge device, V is potential over surge device, n is power number which can be derived from equation (10)

\[ a = \frac{\log I_j - \log I_i}{\log V_j - \log V_i} \]  

(10)

4. Underground pipeline model and Simulation results
Lightning current parameters which difference from [9] can be considered from first stroke where \( r_1 \) equals to 19 micro second, \( \tau_2 \) equals to 485 micro second, \( n \) equals to 10 as follow IEC 61312-1. Its simulation can be considered in 3 categories, 1) consider only pipeline impedance 2) consider impedance from both pipeline and corrosion protection cable and 3) protection for category 2. All categories simulate on pipe length at 500 and 1,000 meters by record instantaneous state at every 100 meters.

Table 2. Transient state on pipeline
value of the devices which enough to cause damage to corrosion protection devices. The result of protection simulation has shown that it can limit instantaneous potential to less than 1,500 volts as follow BS60950 as in figure 7 so this can be applied to use to control potential appear over pipeline.

REFERENCES

[5] Nattaya Klaicuan, Witchuda Sopho, and Pisarn Densunghern, Lightning Performance Improvement of 22 kV Distribution Line, Department of Electrical Engineering, Faculty of Engineering at Suratthana, Kasetsart University Suratthana Campus

5. Conclusion

The analysis of lightning phenomenon for the underground petroleum pipeline and its protection which has been proposed and the result of its simulation which was included in this paper, has shown that the lightning instantaneous potential at the distance along pipeline will higher when pipeline length is increase due to its inductance directly vary to its length as shown in equation (7) and also found that the instantaneous current tend to be decrease as its length increasing as shown in table 2. When considering impedance from pipeline and corrosion protection circuit cable, this analysis found both instantaneous potential and current are higher than safety