

# University of Wollongong - Research Online

## Thesis Collection

Title: Induced currents in gas pipelines due to nearby power lines

Author: Dejan Markovic

Year: 2005

Repository DOI:

### Copyright Warning

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following: This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of this work may be reproduced by any process, nor may any other exclusive right be exercised, without the permission of the author. Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material.

Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

**Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.**

Research Online is the open access repository for the University of Wollongong. For further information contact the UOW Library: [research-pubs@uow.edu.au](mailto:research-pubs@uow.edu.au)

2005

## Induced currents in gas pipelines due to nearby power lines

Dejan Markovic  
*University of Wollongong*

Follow this and additional works at: <https://ro.uow.edu.au/theses>

### University of Wollongong

#### Copyright Warning

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following: This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of this work may be reproduced by any process, nor may any other exclusive right be exercised, without the permission of the author. Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material.

Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.

---

### Recommended Citation

Markovic, Dejan, Induced currents in gas pipelines due to nearby power lines, M.Eng. thesis, School of Electrical, Computer and Telecommunications Engineering, University of Wollongong, 2005.  
<http://ro.uow.edu.au/theses/638>

Research Online is the open access institutional repository for the University of Wollongong. For further information contact the UOW Library: [research-pubs@uow.edu.au](mailto:research-pubs@uow.edu.au)

## **NOTE**

This online version of the thesis may have different page formatting and pagination from the paper copy held in the University of Wollongong Library.

## **UNIVERSITY OF WOLLONGONG**

### **COPYRIGHT WARNING**

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site. You are reminded of the following:

Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material. Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

# **Induced Currents in Gas Pipelines due to Nearby Power Lines**

A thesis submitted in fulfillment of the requirements for the  
award of the degree

**Masters by Research**

from

**University of Wollongong**

by

**Dejan Markovic, BEng**

School of Electrical, Computer and Telecommunications Engineering  
**October 2005**

## CERTIFICATION

I, Dejan Markovic, declare that this thesis, submitted in partial fulfilment of the requirements for the award of Masters by Research, in the School of Electrical, Computer and Telecommunications Engineering, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualification at any other academic institution.

Dejan Markovic

28 October 2005

## **Acknowledgements**

This research would not have been possible without the generous support of the sponsors, Australian natural gas utility, Agility. The author wishes to thank them for their kind assistance.

## Abstract

Significant voltage levels can be induced in gas pipelines due to power lines in areas where they share the same corridor, especially during a fault. These voltages can affect the operating personnel, pipeline-associated equipment, cathodic protection systems and the pipeline itself. Quite often, mitigation is required to reduce these induced voltages to levels that are safe for personnel and integrity of the pipeline. This thesis investigates and evaluates the performance and capabilities of two software packages that have been developed to calculate and manage induced voltages on pipelines, PRC and CDEGS. As it was the superior package, CDEGS and the interference analysis based on it is presented in detail.

The complete interference analysis, including steady state and fault conditions, was performed on the Young-Lithgow pipeline and power line shared corridor. It is shown that pipeline coating stress voltages in excess of levels recommended by the CDEGS procedure may exist for faults on particular power lines. Possible remedial measures are suggested.

Subsequently, the existing mitigation system on the Brisbane pipeline, employing insulating joints with permanent earths, is assessed using CDEGS. It is shown that this mitigation is sufficient in regard to controlling pipeline coating stress voltages. Touch voltages on three test points are in excess of levels allowed by IEEE recommendations, but still within levels allowed by Australian Standards.

The same pipeline layout is used to analyse the hypothetical case of a mitigation system implemented with zinc gradient control wire. While the pipeline coating stress voltages are within recommended limits, only one test point touch voltage is in excess of IEEE recommendations and again all are within Australian Standards limits.

Apart from performance, the two mitigation methods are compared in terms of cost of installation and other features. It is concluded that despite the lower costs of installation of a system with insulating joints, some other features and costs associated with maintenance of the two compared systems favoured the gradient control wire method and made it the preferred method for mitigation of induced currents in pipelines for many configurations.

## Table of Contents

Abstract	iv
1 Introduction	1
1.1 Statement of the Problem . . . . .	1
1.2 Objectives of the Thesis . . . . .	2
1.3 Summary of the Research Methodology . . . . .	2
1.4 Limitations of the Study . . . . .	4
1.4.1 Limitations of Software . . . . .	4
1.4.2 Limitations of Field Measurements . . . . .	4
1.5 Layout of the Thesis . . . . .	6
2 Literature Review	8
2.1 Evolution of Prediction Methods for Induced Voltages on Pipelines . . . . .	8
2.2 Mitigation of Induced Voltages on Pipelines . . . . .	13
2.2.1 Early Grounding Methods . . . . .	13
2.2.2 Cancellation Wire . . . . .	14
2.2.3 Insulating Joints . . . . .	15
2.2.4 Gradient Control Wire . . . . .	18
2.3 Cathodic Protection Considerations . . . . .	19
2.4 Conclusions . . . . .	21
3 Methodologies	23
3.1 Introduction . . . . .	23
3.2 PRC International Software . . . . .	23
3.3 CDEGS software . . . . .	24
3.3.1 Introduction . . . . .	24
3.3.2 Modules . . . . .	24
3.4 Typical CDEGS Pipeline Interference Study Procedure . . . . .	26
3.4.1 Data Collection . . . . .	26
3.4.2 Soil Resistivity Analysis . . . . .	29
3.4.3 Inductive Analysis . . . . .	29
3.4.4 Inductive Analysis and Fault Graphs . . . . .	30
3.4.5 Conductive Analysis . . . . .	30
3.4.6 Total Pipeline Coating Stress Voltage . . . . .	31
3.4.7 Safety Analysis . . . . .	31
3.4.8 Mitigation Design . . . . .	31
3.5 Soil Resistivity Measurements . . . . .	32
3.6 Monitoring of Cathodic Protection Potentials . . . . .	33



4	Comparison of PRC and CDEGS Software and Introduction to Interference Analysis using CDEGS	36
4.1	CDEGS and PRC Software Comparison	36
4.1.1	Consumer Power Company, Kalamazoo Line 1800 Pipeline Case Study	37
4.1.2	Southern California Gas Company Line 325 Needles, Mojave Dessert Pipeline Case Study	40
4.1.3	Features of CDEGS and PRC Packages	43
4.2	Introduction to CDEGS: Young-Lithgow (YL) Pipeline Case Study	43
4.3	Description of the Corridor	43
4.3.1	Pipeline	44
4.3.2	Existing Pipeline Mitigation	45
4.3.3	Power Lines	45
4.3.4	Computer Modelling Procedure	45
4.3.5	Soil Resistivity	46
4.4	Existing Mitigation System	46
4.4.1	Steady State	46
4.4.2	Faults - Inductive Component	48
4.4.3	Faults - Conductive Component and Total Pipeline Coating Stress Voltages	51
4.4.4	Safety Assessment of Test Points	53
4.4.5	Cathodic Protection	55
4.5	Conclusions	55
5	Assessment of Two Mitigation Methods: Brisbane Pipeline Case Study	57
5.1	Introduction	57
5.2	Mitigation Methods	58
5.2.1	Mitigation with Insulating Joints	58
5.2.2	Mitigation with Gradient Control Wire	58
5.3	Description of the Corridor	59
5.3.1	Pipeline	60
5.3.2	Existing Pipeline Mitigation	60
5.3.3	Power Lines	61
5.3.4	Computer Model	61
5.3.5	Soil Resistivity	62
5.3.6	Approximate Calculation of Induced Potentials on Pipeline	62
5.4	Existing Mitigation System with Insulating Joints	64
5.4.1	Steady State	64
5.4.2	Faults - Inductive Component	67
5.4.3	Faults - Conductive Component and Total Pipeline Coating Stress Voltages	69
5.4.4	Safety Assessment of Test Points	70
5.4.5	Cathodic Protection	74
5.4.6	Costing	77
5.5	Alternative Mitigation Design with Gradient Control Wire	78
5.5.1	Steady State	78

5.5.2	Faults - Inductive Component . . . . .	79
5.5.3	Faults - Conductive Component and Total Pipeline Coating Stress Voltages . . . . .	79
5.5.4	Considerations in relation to Fault at Tower 2243 . . . . .	80
5.5.5	Safety Assessment of Test Points . . . . .	81
5.5.6	Cathodic Protection . . . . .	84
5.5.7	Costing . . . . .	86
5.6	Comparison of the two mitigation systems . . . . .	87
5.6.1	Costs . . . . .	87
5.6.2	Mitigation . . . . .	87
5.6.3	Maintenance and Repair . . . . .	88
5.6.4	Cathodic Protection . . . . .	88
5.6.5	Pipeline and Mitigation System Decoupling . . . . .	88
5.7	Conclusions . . . . .	89
6	Conclusions, Guidelines and Recommendations . . . . .	90
6.1	Conclusions . . . . .	90
6.2	Guidelines on How to Choose an Appropriate Mitigation Method . . . . .	91
6.3	Recommendations for Future Research . . . . .	91
A	Brief Theory of Pipeline and Power Line Interference . . . . .	93
A.1	Calculations of Induction Levels . . . . .	93
A.2	Calculation of Metallic Pipeline Electrical Parameters . . . . .	96
A.2.1	Symbols Used . . . . .	96
A.2.2	Pipeline Series Impedance . . . . .	97
A.2.3	Pipeline Admittance . . . . .	97
A.2.4	Pipeline Characteristic Impedance ( $\Omega$ ) . . . . .	97
A.2.5	Pipeline Propagation Constant ( $1/m$ ) . . . . .	97
A.2.6	Characteristic Length of Pipeline . . . . .	97
B	Fault Current Components . . . . .	98
B.1	Calculation of Power Line Zero Sequence Impedance for a Single Circuit Horizontal Tower With Two Earth Wires . . . . .	98
B.2	Calculation of Fault Current Component . . . . .	101
C	Two Layer Computer Soil Model . . . . .	104
C.1	Young-Lithgow Corridor Soil Model . . . . .	104
C.2	Brisbane Corridor Soil Model . . . . .	106
C.3	Brisbane Corridor Soil Model for Cathodic Protection Calculations with Insulating Joints . . . . .	107
C.4	Brisbane Corridor Soil Model for Cathodic Protection Calculations with Gradient Control Wire . . . . .	107

D	Power Line Data	108
D.1	Young-Lithgow Corridor Power Line Data . . . . .	108
D.2	Brisbane Corridor Power Line Data . . . . .	110
D.3	Brisbane Corridor Power Line Tower Footing Resistances . . . . .	111
D.4	Estimation of Fault Current Components . . . . .	111
D.4.1	Location of Power Line Faults . . . . .	111
D.4.2	Worst Case Scenario Fault Current Components . . . . .	112
E	Nomogram	113
E.1	Nomogram for Calculation of Mutual Impedance . . . . .	113
	References	115

## List of Figures

1.1	Flowchart of the research methodology . . . . .	3
3.1	Soil resistivity measurement - Wenner method . . . . .	32
3.2	Cathodic protection levels logs at Brewongle on Young-Lithgow pipeline . .	34
4.1	Kalamazoo pipeline - corridor profile and steady state potentials . . . . .	37
4.2	Kalamazoo pipeline with insulating joint removed - steady state potentials .	38
4.3	Kalamazoo pipeline with insulating joint bonded - steady state potentials .	38
4.4	Mojave desert pipeline - shared corridor geometry . . . . .	40
4.5	Mojave desert pipeline - steady state potentials . . . . .	41
4.6	Mojave desert pipeline - comparisons of steady state potentials . . . . .	41
4.7	Young-Lithgow pipeline - physical layout of the shared corridor (not drawn to scale) . . . . .	44
4.8	Young-Lithgow pipeline - steady state potentials . . . . .	47
4.9	Young-Lithgow pipeline - inductive component of coating stress voltage for faults along power line 94x . . . . .	50
4.10	Young-Lithgow pipeline - inductive component of coating stress voltage for faults along power line 944 . . . . .	50
4.11	Young-Lithgow pipeline - inductive component of coating stress voltage for faults along power line 934 . . . . .	51
4.12	Young-Lithgow pipeline - inductive component of coating stress voltage for faults along power line 94x - with extra grounding at points 180.1 and 200 .	54
4.13	Young-Lithgow - inductive component of coating stress voltage for faults along power line 944 - with extra grounding at points 180.1 and 200 . . . .	54
5.1	Mitigation system with insulating joints . . . . .	58
5.2	Mitigation system with gradient control wire . . . . .	59
5.3	Brisbane pipeline - physical layout of shared corridor (not drawn to scale) .	60
5.4	Brisbane pipeline with no insulating joints - steady state potentials . . . . .	64
5.5	Brisbane pipeline with insulating joints at termination points - steady state potentials . . . . .	65
5.6	Brisbane pipeline with 8 insulating joints - steady state potentials . . . . .	65
5.7	Brisbane pipeline with no insulating joints - inductive component of coating stress voltage for faults along power line 817 . . . . .	66
5.8	Brisbane pipeline with insulating joints at termination points - inductive component of coating stress voltage for faults along power line 817 . . . . .	67
5.9	Brisbane pipeline with eight insulating joints - inductive component of coating stress voltage for faults along power line 817 . . . . .	68
5.10	Brisbane pipeline with eight insulating joints and permanent earths - inductive component of coating stress voltage for faults along power line 817 . . .	69
5.11	Brisbane pipeline with insulating joints, test point 1, fault at 2226 - conductive touch voltage distribution . . . . .	71
5.12	Brisbane pipeline with gradient control wire - steady state potentials . . . .	79

5.13	Brisbane pipeline with gradient control wire - inductive component of coating stress voltage for faults along power line 817 . . . . .	80
A.1	Equivalent pipeline circuit (increment) . . . . .	94
B.1	Single circuit horizontal tower dimensions . . . . .	99
B.2	Simple system illustrating left and right fault current components . . . . .	102
D.1	Brisbane power line - left and right fault components for selected faults . .	112
E.1	Nomogram for calculation of mutual impedance per unit length ( $f = 50 \text{ Hz}$ )	114

## List of Tables

4.1	Young-Lithgow pipeline - total pipeline coating stress voltages . . . . .	52
5.1	Brisbane pipeline with insulating joints - total pipeline coating stress voltages	70
5.2	Brisbane pipeline with insulating joints - test points touch voltages . . . . .	72
5.3	Brisbane pipeline with insulating joints - cathodic protection current densities ( $\mu A/m^2$ ) . . . . .	77
5.4	Brisbane pipeline with gradient control wire - total pipeline coating stress voltages . . . . .	81
5.5	Brisbane pipeline with gradient control wire - test point touch voltages . . .	82
5.6	Brisbane pipeline with gradient control wire, test point 5, faults at tower 2239 - touch voltages mitigation design . . . . .	83
5.7	Brisbane pipeline with gradient control wire - cathodic protection current densities ( $\mu A/m^2$ ) . . . . .	85
C.1	Young-Lithgow pipeline - field measurements and corresponding computer soil model, Part 1 . . . . .	104
C.2	Young-Lithgow pipeline - field measurements and corresponding computer soil model, Part 2 . . . . .	105
C.3	Brisbane pipeline - field measurements and corresponding computer soil model	106
C.4	Brisbane pipeline with insulating joints - soil model used for cathodic pro- tection calculations . . . . .	107
C.5	Brisbane pipeline with gradient control wire - soil model used for cathodic protection calculations . . . . .	107
D.1	Young-Lithgow power line data . . . . .	109
D.2	Brisbane power line data . . . . .	110
D.3	Brisbane power line tower footing resistances . . . . .	111