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Transient behaviour modelling of underground high voltage cable systems

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Transient Behaviour Modelling of Underground High Voltage Cable Systems

A thesis submitted in partial fulfilment of the
requirements for the award of the degree

Master of Engineering - Research

from

University of Wollongong

by

Muhamad Zalani Daud, BEng

School of Electrical, Computer and Telecommunications Engineering

July 2009

To my wife, my son and my late mum

Abstract

The behaviour of voltage and current transients when a high voltage (HV) cable is first energised is a problem of practical significance to utilities. Modelling of this behaviour on a suitable simulation platform is an attractive approach, in many cases, provided that the results closely match real-world behaviour. This thesis presents modelling and analysis of transients resulting from energisation of an unloaded cable using PSCAD[®]/EMTDC[™] simulation software. An assessment of the applicability of existing frequency-dependent (FD) cable models is given. The impact of transients on a simulated cable system is also presented and discussed.

In cable system modelling, system components must be accurately modelled, primarily the underground cable. Two common frequency-dependent cable models are based on the travelling wave method, namely the FD-Mode and FD-Phase models. These models are investigated by comparing their ability to predict energisation current transients resulting from the switching of an unloaded 132 kV underground cable. The simulated results are validated by comparison with the measurement data. It was found that, the FD-Phase model provides more accurate results compared to the FD-Mode model. This model is widely applicable and suitable for use in modelling a wide range of frequencies.

The FD-Phase model was used in this study to analyse the distribution of overvoltages at sending and receiving ends of the cable system. Specifically, statistical analysis has been carried out correlating the overvoltage magnitudes induced and the closing behaviour of the circuit breaker (CB). Two statistical switching techniques have been applied, namely the deterministic and probabilistic approaches. Based on the approaches studied, results from probabilistic techniques are recommended owing to the fact that it is closer to reality.

Certification

I, Muhamad Zalani Daud, declare that this thesis, submitted in partial fulfilment of the requirements for the award of Master of Engineering - Research, in the School of Electrical, Computer and Telecommunications Engineering at the 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.

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Muhamad Zalani Daud

July 7, 2009

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Publications arising from this Thesis

1. M. Z. Daud, P. Ciufu, S. Perera, *Investigation on the suitability of PSCAD[®]/EMTDC[™] models to study energisation transients of 132 kV underground cable*, Proc. Australasian Universities Power Engineering Conference (AUPEC 2008), Paper ID: 037, December 2008, Sydney, Australia.
2. M. Z. Daud, P. Ciufu, S. Perera, *Statistical analysis of overvoltages due to the energisation of a 132 kV underground cable*, Proc. Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology Conference (ECTI-CON 2009), Paper ID: 1325, May 2009, Bangkok, Thailand.

Table of Contents

Abstract	iii
Certification	iv
Acknowledgements	v
List of Publications	vi
List of Abbreviations	x
List of Figures	xi
List of Tables	xiii
1 Introduction	1
1.1 Statement of the Problem	1
1.2 Objectives of the Thesis	4
1.3 Contributions	5
1.4 Outline of the Thesis	5
2 Literature Review	7
2.1 Introduction	7
2.2 Transients and Travelling Waves	8
2.3 Cable Modelling	10
2.3.1 The Wave Equations	10
2.3.2 Coaxial Cable Electrical Parameters	11
2.3.3 Impedance and Admittance Matrices	12
2.4 An Overview of Approaches and Existing Models	13
2.4.1 Electromagnetic Transients Simulation	13
2.4.2 Lumped Pi Models	15
2.4.3 Distributed Parameter Travelling Wave Models	15
2.5 PSCAD [®] /EMTDC [™] Cable Models	17
2.5.1 The FD-Mode Model	17
2.5.2 The FD-Phase Model	20
2.6 Analysis of Switching Transient Overvoltages	21
2.6.1 An Overview of Statistical Switching Studies	21
2.6.2 Switching Phenomena and Statistical Methods	22
2.7 Summary	24
3 PSCAD [®] /EMTDC [™] Power System Model Development	25
3.1 Introduction	25
3.2 Power System Network	26
3.3 Power System Component Modelling	27
3.3.1 132 kV Upstream Power Source	27
3.3.2 Transmission Lines	29

3.3.3	Transformer and Capacitor Bank	30
3.4	Underground cable	31
3.4.1	Physical Construction and Material Properties	31
3.4.2	Cable Configuration	34
3.5	Inclusion of FD-Mode and FD-Phase Models in the Simulation	35
3.5.1	Frequency-dependent Parameter Settings	35
3.5.2	Simulation Step Size and Simulation Time	37
3.6	Results from Simulation of Preliminary PSCAD [®] /EMTDC [™] Model	37
3.7	Summary	40
4	Cable Energisation Transient Behaviour and Assessment of Cable Models	42
4.1	Introduction	42
4.2	Experimental Energisation Tests	43
4.2.1	Measurement Method	43
4.2.2	Measured Current Transient Waveforms	44
4.2.3	Data for Comparison	46
4.2.4	Analysis of the CB Pole Closing Times	48
4.3	Model Refinement and Simulation	49
4.3.1	Implementation of CB Pole Closing Times to the Circuit Model	49
4.3.2	Simulation	50
4.4	Comparison of Results Predicted by FD-Mode and FD-Phase Models	50
4.4.1	Simulation using FD-Mode Model	50
4.4.2	Simulation using FD-Phase Model	53
4.4.3	Implication from Measured and Simulated Data	55
4.5	Overvoltage Transient Behaviour for the System Under Study	57
4.6	Summary	60
5	Analysis of Overvoltage Stress due to Cable Energisation	62
5.1	Introduction	62
5.2	An Overview of Switching Transient Evaluation Methods	63
5.3	Simulation Approaches	64
5.3.1	First Approach (Deterministic)	64
5.3.2	Second Approach (Probabilistic)	65
5.4	Model Refinement and Simulation	66
5.4.1	Implementation of Deterministic Approach in Simulation	66
5.4.2	Implementation of Probabilistic Approach in Simulation	67
5.5	Analysis of Overvoltage Data from Simulation	68
5.5.1	Results from Deterministic Approach	69
5.5.2	Results from Probabilistic Approach	70
5.5.3	Results for the Pole Span below 1 ms	72
5.6	Summary	74
6	Conclusions and Recommendations	76
6.1	Conclusions	76
6.2	Recommendations	78

Appendices

A	Fundamental Equations in Cable Modelling	79
A.1	The General Transmission Lines or Wave Equations	79
A.2	Coaxial Cable Electrical Parameters	81
A.3	Impedance and Admittance Matrices	83
B	Power System Component Data	84
B.1	Input Parameter Calculation of Surrounding Components	84
B.2	Underground Cable Data	89
C	Measurement Data	95
C.1	Current Transients from Experimental Energisation Tests	95
C.2	CB Pole Closing Times from Experimental Energisation Tests	99
	References	100

List of Abbreviations

HV	<u>h</u> igh <u>v</u> oltage
EHV	<u>e</u> xtra <u>h</u> igh <u>v</u> oltage
UHV	<u>u</u> ltra <u>h</u> igh <u>v</u> oltage
IEC	<u>I</u> nternational <u>E</u> lectrotechnical <u>C</u> ommission
IEEE	<u>I</u> nstitute of <u>E</u> lectrical and <u>E</u> lectronics <u>E</u> ngineers
EMTP	<u>e</u> lectromagnetic <u>t</u> ransients <u>p</u> rogram
DC	<u>d</u> irect <u>c</u> urrent
FD	<u>f</u> requency- <u>d</u> ependent
CB	<u>c</u> ircuit <u>b</u> reaker
ULM	<u>u</u> niversal <u>l</u> ine <u>m</u> odel
CC	<u>c</u> able <u>c</u> onstant
CF	<u>c</u> urve <u>f</u> itting
BHTS	<u>B</u> aulkham <u>H</u> ills <u>t</u> ransmission <u>s</u> ubstation
BVZS	<u>B</u> ella <u>V</u> ista <u>z</u> one <u>s</u> ubstation
BTTS	<u>B</u> lack <u>t</u> own <u>t</u> ransmission <u>s</u> ubstation
SWTS	<u>S</u> ydney <u>W</u> est <u>t</u> ransmission <u>s</u> ubstation
CFTS	<u>C</u> arlingford <u>t</u> ransmission <u>s</u> ubstation
XLPE	cross-linked polyethylene
PVC	<u>p</u> oly <u>v</u> inyl <u>c</u> hloride
HDPE	<u>h</u> igh- <u>d</u> ensity <u>p</u> olyethylene
SVL	<u>s</u> heath <u>v</u> oltage <u>l</u> imiter
RMS	<u>r</u> oot <u>m</u> ean <u>s</u> quare
FFT	<u>f</u> ast <u>F</u> ourier <u>t</u> ransform
VT	<u>v</u> oltage <u>t</u> ransformer
TV	<u>t</u> ertiary <u>v</u> oltage
PDF	<u>p</u> robability <u>d</u> ensity <u>f</u> unction
CDF	<u>c</u> umulative <u>d</u> ensity <u>f</u> unction
SE	<u>s</u> ending <u>e</u> nd
RE	<u>r</u> eceiving <u>e</u> nd

List of Figures

2.1	Single phase frequency domain equivalent circuit of FD-Mode model	17
2.2	Weighting Function from J Marti formulation	19
2.3	Typical 2 % slow-front overvoltage values	23
3.1	Single line schematic diagram of power system network under study	27
3.2	Overhead line representation in PSCAD [®] /EMTDC [™]	30
3.3	Cable cross-section	31
3.4	Cable input data in PSCAD [®] /EMTDC [™]	33
3.5	Cross-bonding and configuration of the cable	35
3.6	Current transients from preliminary FD-Mode model at $T = 10$ kHz	38
3.7	Current transients from preliminary FD-Phase model	38
3.8	Current transients from preliminary FD-Mode model at $T = 50$ Hz	39
3.9	Overtoltage transients at the sending end of the cable	40
4.1	Cable energisation test set-up	44
4.2	Current transients from measurement data	45
4.3	Blue and white phase current transients from third measurement	46
4.4	Frequency spectrum of blue and white phase current transients	48
4.5	Determination of CB pole closing times from third energisation test	49
4.6	Establishment of CB pole closing times in PSCAD [®] /EMTDC [™]	49
4.7	Simulated current transients from FD-Mode model	52
4.8	Frequency spectrum of simulated current transients using FD-Mode model .	52
4.9	Simulated current transients from FD-Phase model	54
4.10	Frequency spectrum of simulated current transients using FD-Phase model	54
4.11	Steady-state charging current for cable under test	55
4.12	An example of high frequency transformer model	57
4.13	Overtoltage transients at sending and receiving end terminals	58
4.14	Busbar voltages during cable energisation	59
4.15	Sheath voltages during switching with and without surge arresters	60
5.1	Gaussian distribution curve	65
5.2	Implementation of deterministic approach	67
5.3	Results from deterministic approach	69
5.4	Results from probabilistic approach for 1 ms, 2 ms and 3 ms spans	71
5.5	Results from probabilistic approach for below 1 ms pole span	73
A.1	A Δx section of a coaxial cable	80
A.2	A simplified coaxial cable cross-sectional area	81
B.1	Current transients simulated using two different source models	86
B.2	Overhead line conductor co-ordinates	87
C.1	Blue and white phase current transients from first measurement	95
C.2	Blue and white phase current transients from second measurement	96
C.3	Blue and white phase current transients from fourth measurement	96
C.4	Frequency spectrum of current transients from first measurement	97

C.5	Frequency spectrum of current transients from second measurement	97
C.6	Frequency spectrum of current transients from fourth measurement	98
C.7	CB pole closing times for each test	99

List of Tables

3.1	Source model input data of voltage source model-2	28
3.2	Cable layers radial measurements	31
3.3	Cable dimensions and material properties input data	34
3.4	Cable coordinates input data	34
5.1	CB pole switching times and maximum span from each test	64
5.2	Red phase magnitudes for different simulation time step	66
5.3	Sending end voltage magnitudes from simultaneous closure of CB	68
5.4	Significant overvoltage peaks from deterministic approach	70
5.5	Relevant statistical information for different cases of pole span	74
B.1	Calculation of sequence impedances for voltage source model-1 and model-2	85
B.2	132 kV overhead line general data	86
B.3	Conductor and ground wire data	86
B.4	Transformer general data	87
B.5	Transformer positive sequence leakage reactance data	87
B.6	Cable data from manufacturer	89