ONSITE MEASUREMENT TECHNIQUES AND MODELLING TO MINIMIZE MAGNETIC FIELD STRENGTH UNDER OVERHEAD TRANSMISSION LINES

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A thesis submitted in
fulfilment of the requirement for the award of the
Doctor of Philosophy in Electrical Engineering

Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia

DECEMBER 2022

Dedicated to my dearest family
especially *Mama* and *Abah*

ACKNOWLEDGEMENT

Above all, I pray to Allah the Almighty for His Kindness and Blessing throughout my journey upon completing this thesis.

I want to express my sincere gratitude to my academic supervisor, Assoc. Prof. Dr. Md Nor Ramdon bin Baharom for his constant invaluable guidance, encouragement, patience, and understanding through and through securing the success of this research.

Special thanks to the Ministry of Higher Education Malaysia and Universiti Tun Hussein Onn Malaysia for their sponsorship and financial support, especially RMC and EMCenter. Not to forget, FKEE staffs and personnel of which provided a lending hand in every technical aspect.

The highest honour I give to my parents, family, and wife for their never-ending support and trust in every way imaginable, for every up and down, they are there for me to rely on.

There are no words sufficient to describe my appreciation and gratitude to all those who have supported me. In all humbleness, I say thank you.

ABSTRACT

This research aims to provide thorough planning of magnetic field (MF) level measurement execution in a residential area within the vicinity of overhead transmission lines (OTL). The expected outcome of the measurement is to provide a meticulous set of MF level profiling radiated from OTL in a large area. The MF level profiling recorded can also determine whether it complies with the MF exposure limit of 100 μT as provided by the International Commission of Non-Ionizing Radiation Protection (ICNIRP). Conducted in Kolej Kediaman Bestari UTHM as a case study, MF radiation from 132 kV and 275 kV power lines in that area are recorded throughout three different stages of development (during construction, after construction while vacant, and after construction while occupied). The MF at a maximum of 1 μT is recorded throughout the measurements, and the presence of MF level radiation from sources other than the OTL is observed. In addition to that, a few solutions for reducing MF radiation from OTL systems are proposed, which are the implementation of conductor phase rearrangements, reconductoring and composite cross-arms. These solutions heavily emphasize the modifications of existing OTL systems, which also provide the opportunity to improve ampacity. Data regarding these solutions are obtained through mathematical calculation and Ansys Maxwell engineering software simulation based on IEEE standards, CIGRE and other researchers. By analysing these data, existing OTL systems in Malaysia can be enhanced with the correct combination of solutions, up to 65% MF reduction or up to 52% ampacity increment. Therefore, this research's MF level measurement planning can serve as a guideline for personal and commercial gains. The solutions proposed can offer a healthier living environment while coping with the increasing electricity demands.

ABSTRAK

Kajian ini bertujuan menyediakan perancangan pengukuran aras medan magnet secara teliti dalam kawasan kediaman berhampiran dengan talian penghantaran atas kepala (OTL). Hasil pengukuran dijangka memberikan satu set profil aras medan magnet yang teliti dalam kawasan yang luas akibat radiasi daripada OTL. Pemprofilan tahap medan magnet yang direkodkan juga boleh digunakan untuk menentukan sama ada ia mematuhi had pendedahan medan magnet 100 μT seperti yang ditetapkan oleh *International Commision of Non-Ionizing Radiation Protection (ICNIRP)*. Menggunakan Kolej Kediaman Bestari UTHM sebagai kajian kes, radiasi medan magnet daripada talian kuasa 132 kV dan 275 kV di kawasan tersebut direkodkan dalam tiga peringkat pembangunan yang berbeza (semasa pembinaan, selepas pembinaan tanpa penghuni, dan selepas pembinaan dengan penghuni). Sepanjang pengukuran, medan magnet setinggi 1 μT direkodkan, dan kehadiran radiasi medan magnet daripada sumber lain diperhatikan. Di samping itu, beberapa penyelesaian ke arah pengurangan radiasi medan magnet daripada sistem OTL dicadangkan, menerusi perlaksanaan penyusunan semula fasa kabel, penggantian kabel dan *composite cross-arm*. Penyelesaian ini menekankan kepada pengubahsuaian sistem OTL sedia ada, yang juga membuka peluang untuk meningkatkan kadaran arus. Data mengenai penyelesaian ini diperolehi melalui pengiraan matematik dan simulasi menggunakan perisian kejuruteraan Ansys berdasarkan piawaian IEEE, CIGRE dan penyelidik lain. Dengan menganalisis data ini, sistem OTL sedia ada di Malaysia boleh dipertingkatkan menggunakan gabungan penyelesaian yang sesuai, sehingga 65% pengurangan medan magnet atau sehingga 52% peningkatan kadaran arus. Oleh itu, perancangan pengukuran aras medan magnet yang dibentangkan dalam penyelidikan ini boleh dijadikan garis panduan bagi kepentingan peribadi atau komersial, manakala penyelesaian yang dicadangkan boleh menawarkan persekitaran hidup yang lebih sihat di samping sebagai persediaan menghadapi permintaan elektrik yang semakin meningkat.

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LIST OF SYMBOLS AND ABBREVIATIONS

°C	-	degree Celcius
μ	-	relative permeability
μT	-	micro Tesla
A	-	Ampere
B_k	-	the instantaneous value of magnetic flux density
c	-	catenary constant, T/w
D	-	distance
d	-	conductor diameter
E	-	effective modulus of elasticity
E_S	-	elastic stretch
E_T	-	conductor's extension due to any change of temperature
F_W	-	wind pressure
H_e	-	elevation of the conductor above sea level
Hz	-	Hertz
I	-	current
kN	-	kiloNewton
kV	-	kiloVolt
L	-	span length
l	-	length of span measured along the conductor (the arc length),
Lat	-	degree of latitude
LHS	-	left-hand-side
m	-	meter
MHz	-	mega Hertz
m_{ice}	-	ice mass

mm	-	millimeter
ms	-	milliseconds
MWT	-	maximum weight tension
N_d	-	day of the year
N	-	total number of instantaneous magnetic flux density profiles, 73
p	-	estimated wind pressure
q_c	-	convective heat loss rate
q_r	-	radiated heat loss rate
q_s	-	solar heat gain rate
R_{ac}	-	conductor's AC resistance
RHS	-	right-hand-side
R_{T_C}	-	50 Hz AC resistance of conductor at operating temperature T_C
$R_{T_{Calc}}$	-	resistance calculated at temperature T_C
R_{T_H}	-	50 Hz ac resistance at temperature T_H
R_{T_L}	-	50 Hz ac resistance at temperature T_L
S	-	siemens
S_c	-	sag of the conductor at mid-span
T	-	horizontal component of tension
T_1	-	reduced maximum working tension
T_a	-	ambient temperature
T_c	-	conductor temperature at which the new 50 Hz resistance is desired
T_f	-	final horizontal component of tension
T_H	-	high conductor temperature at which the resistance, R_{T_H} is specified
T_i	-	initial horizontal component of tension
T_L	-	low conductor temperature at which the resistance, R_{T_L} is specified
T_r	-	conductor's rated tensile strength
u	-	wind speed
V	-	volt

w	-	either vertical force in still air, or resultant force with wind, per unit length of conductor in the span
x	-	horizontal distance from the origin or lowest point in the span
α	-	a defined increase of diameter due to ice
α_e	-	effective coefficient of expansion
α_{ice}	-	defined increase of diameter due to ice
α_{solar}	-	solar absorptivity
ε	-	emissivity
θ_1	-	initial temperature
θ_2	-	final temperature
θ_{max}	-	maximum temperature
θ_{min}	-	minimum temperature
σ_a	-	conductor cross-sectional area
σ_c	-	electrical conductivity
Ω	-	ohmic resistance
ω	-	hour angle
Φ	-	the angle between wind direction and conductor axis
2D	-	2-Dimensional
3D	-	3-Dimensional
AC	-	alternating current
Al	-	aluminium
CCA	-	composite cross-arms
COVID-19	-	coronavirus disease
CWT	-	conductor working temperature
DNA	-	deoxyribonucleic
EF	-	electric field
ELF	-	extremely low frequency
EMF	-	electromagnetic field
FOS	-	factor of safety
MCO	-	movement control order

MF	-	magnetic field
N/A	-	not available
OH	-	hydroxyl
OTL	-	overhead transmission line
PMU	-	primary intake substation
RMS	-	root-mean-square
ROW	-	right-of-way
RYB	-	red-yellow-blue
St	-	steel
AAAC	-	All Aluminium Alloy Conductor
AAC	-	All Aluminium Conductor
ACAR	-	Aluminium Conductor Alloy Reinforced
ACCC/TW	-	Aluminium Conductor Composite Core / Trapezoidal Wire
ACCR	-	Aluminium Conductor Composite Reinforced
ACSR	-	Aluminium Conductor Steel Reinforced
ACSS	-	Aluminium Conductor Steel Supported
BOLD®	-	Breakthrough Overhead Line Design
BSI	-	British Standards International
CEGB	-	Central Electricity Generating Board
CIGRE	-	International Council for Large Electric Systems
DOSM	-	Department of Statistics Malaysia
GTACSR	-	Gap-Type Thermal Resistant Aluminium Alloy Conductor Steel Reinforced
GUI	-	graphical user interface
HTLS	-	High-Temperature Low Sag
IARC	-	International Agency for Research on Cancer
ICNIRP	-	International Commission on Non-Ionizing Radiation Protection
IEEE	-	Institute of Electrical and Electronics Engineers
KKB	-	Kolej Kediaman Bestari UTHM
MEIH	-	Malaysia Energy Information Hub

ST	-	Suruhanjaya Tenaga
TNB	-	Tenaga Nasional Berhad
USA	-	United States of America
UTHM	-	Universiti Tun Hussein Onn Malaysia
ZTACIR	-	Super Thermal Resistant Aluminium Alloy Conductor Steel Reinforced

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Appendix K List of publications

i. H.M. Luqman, M.N.R. Baharom, Z. Zainal, Irshad Ullah, Irfan Ali, "Improvement of the sag ampacity carrying level of existing 275 kV overhead line tower by using the re-conductoring approach", Asian Research Publishing Network (ARPN) Journal of Engineering and Applied Sciences, 2015. ISSN 1819-6608.

ii. H.M. Luqman, M.N.R. Baharom, Irshad Ullah, Z. Zainal, "Magnetic field measurement from 132 kV and 275 kV overhead transmission lines within residential area", International Journal of Simulation: Systems, Science and Technology (IJSSST), 2016. ISSN: 1473-804x online, 1473-8031 print.

iii. H.M. Luqman, M.N.R. Baharom, H. Ahmad, Irshad Ullah, "Planning and conducting magnetic field level measurement from overhead transmission line", International Journal of Electrical and Computer Engineering (IJECE), 2017. ISSN: 2088-8708.

iv. H.M. Luqman, M.N.R. Baharom, N.A.M. Jamail, N.A. Othman, R.Abd. Rahman, M.F.M. Yousof, Irshad Ullah, "Conductor sag comparison for 132 kV overhead transmission line improvement in Malaysia", Bulletin of Electrical Engineering and Informatics (BEEI), 2020. ISSN: 2302-9285.