UNIVERSIDAD
AUTONOMA
METROPOLITANA
Casa abierta al tiempo Azcapotzalco

ENERGIA.174.2015.

26 de marzo de 2015.

Dr. Luis Noreña Franco
Presidente del Consejo Divisional de
Ciencias Básicas e Ingeniería

Estimado Dr. Noreña:

Por medio de la presente informo a usted que al interior del Departamento de Energía acordamos solicitar a usted atentamente convoque a un Consejo Divisional Extraordinario para analizar el informe del Dr. Maximov Serguei y aprobar, en su caso, la prórroga de la Cátedra Michael Faraday que ocupa actualmente.

Sin más por el momento aprovecho la ocasión para enviarle un cordial saludo.

Atentamente,
"Casa Abierta al Tiempo"

[redacted]

Dra. Margarita M. González Brambila
Jefa del Departamento de Energía

2 6 MAR. 2015
10:28
SECRETARIA ACADEMICA
CIENCIAS BASICAS E INGENIERIA

c.c.p. Dra. Lourdes Delgado Núñez.- Secretaria Académica de la División de C.B.I.
expediente /consecutivo
nta*.

**Universidad
Autónoma
Metropolitana**
Casa abierta al tiempo Azcapotzalco

División de Ciencias Básicas e Ingeniería
Departamento de Energía

ENERGIA.128.15
3 de marzo de 2015

Dr. Luis Noreña Franco
Director de la División de Ciencias Básicas e Ingeniería
Unidad Azcapotzalco, UAM

Por este conducto quiero solicitar su amable intervención para que de acuerdo con lo estipulado en el artículo 156-12 del Reglamento de Promoción y Permanencia del Personal Académico se someta a la consideración del Consejo Divisional de CBI la prórroga por un año más del Dr. Serguei Maximov dentro de la Cátedra Michael Faraday.

Atentamente

[redacted]

Dra. Margarita M. González Brambila
Jefa del Departamento de Energía

Casa abierta al tiempo
UNIVERSIDAD AUTÓNOMA METROPOLITANA

SRT-27

SOLICITUD DE PRÓRROGA DE PERSONAL ACADÉMICO

SECRETARIO GENERAL

M. EN C. Q. NOBERTO MANJARREZ ALVAREZ	FECHA	DÍA 05	MES 03	AÑO 2015

CONFORME A LO PREVISTO EN EL REGLAMENTO DE INGRESO, PROMOCIÓN Y PERMANENCIA DEL PERSONAL ACADÉMICO ARTÍCULOS 151 BIS, 156, 156-12 SE SOLICITA LA SIGUIENTE PRÓRROGA:

CONCURSO DE EVALUACIÓN CURRICULAR ☐ PERSONAL ACADÉMICO VISITANTE PERSONAL ACADÉMICO QUE OCUPA CÁTEDRA ☑

No. DE CONVOCATORIA

NOMBRE DE LA CÁTEDRA
"MICHAEL FARADAY"

APELLIDO PATERNO	APELLIDO MATERNO	NOMBRE (S)	No. DE EMPLEADO
	MAXIMOV	SERGUEI	38411
UNIDAD AZCAPOTZALCO		DIVISIÓN CIENCIAS BÁSICAS E INGENIERÍA	

DEPARTAMENTO
ENERGIA

CATEGORÍA Y NIVEL PROFESOR TITULAR "C"	TIEMPO DE DEDICACIÓN COMPLETO

HORARIO
LUNES- VIERNES 10:00 - 18:00

	DÍA	MES	AÑO		DÍA	MES	AÑO	No. DE PLAZA DEFINITIVA QUE CUBRE (sólo en caso de evaluación curricular)
FECHA DE INICIO DE LA CONTRATACIÓN	01	04	2014	FECHA DE TÉRMINO DE LA CONTRATACIÓN	31	03	2015	
FECHA DE INICIO DE LA PRÓRROGA	01	04	2015	FECHA DE TÉRMINO DE LA PRÓRROGA	31	03	2016	

ACTIVIDADES A REALIZAR

Impartir cursos de licenciatura y posgrado relacionados con computación, electricidad y magnetismo tales como: Teoría Electromagnética, Laboratorio de Eelectromagnetismo,CircuitosElctricos I, II, III, Física IV. Métodos Numéricos en Ingeniería, Cinemática y Dinámica de Partículas, Dinámica del cuerpo Rígido, Introducción a la Electrostática y Magnetostática, Complementos de Matemáticas, Matemáticas Aplicadas a la Ingeniería, Cálculo Avanzado con Aplicación y demás que sean necesarias. Apoyar en Proyectos de Investigación correspondientes al Área de Ingeniería Energética y Electromagnética, en particular: Electromagnetismo computacional y Transformadores.
Participar en los siguientes temas de investigación:
1.Cálculo analítico de parámetros eléctricos de transformadores de potencia tipo núcleo y acorazado utilizando funciones especiales para estudiar su comportamiento transitorio.
2. Métodos analíticos para el cálculo de impedancias de transformadores con núcleos ferromagnéticos laminados de diferentes geometrícas (cilíndrica, toroidal, etc).
3. Cálculo analítico de perdidas en las paredes de tanques de transformadores de potencia en los casos de tanque de acero al carbón y acero inoxidable.
4. Modelos analíticos para el diagnóstico en línea de transformadores de potencia.
Formación de Recursos Humanos:
Dirigir y/o codirigir proyectos terminales de las licenciaturas en ingeniería Ele ctrica y Física. Impartir seminarios de investigación y o talleres dirigidos a los profesores del núcleo básico del Área Ingeniería Energética y electromagnética.

DOCUMENTOS QUE ANEXA

DOCUMENTOS PROBATORIOS DE LA SUBSISTENCIA DE LA NECESIDAD ACADÉMICA
PROYECTO DE CONTRATO ANTERIOR ☑
FORMA MIGRATORIA (FM)
INFORME DE ACTIVIDADES ACADÉMICAS ☑
PASAPORTE

DIRECTOR DE DIVISIÓN
DR. LUIS ENRIQUE NOREÑA FRANCO
NOMBRE Y FIRMA

JEFE DE DEPARTAMENTO
[redacted]
DRA. MARGARITA MERCEDES GONZALEZ BRAMBILA
NOMBRE Y FIRMA

Para uso exclusivo de los Profesores Visitantes y de Cátedra
[redacted]
NOMBRE Y FIRMA

Ads 22001

T1 Rector General - DIPPA
T2 Rector de Unidad
T3 Director de División
T4 Jefe de Departamento
T5 DIPPA
T6 Consejo Divisional

Plaza 3374

México D. F. 11 de marzo de 2015

Dra. Margarita M. González Brambila
Jefa del Departamento de Energia

Presente

En virtud de la excelente colaboración en investigación y docencia que el Área de Investigación de Ingeniería Energética y Electromagnética tiene con el Dr. Serguey Maximov, le quiero hacer saber el gran interés del Área en solicitar una prórroga de contratación por un año más para la Cátedra Michael Faraday que actualmente ocupa el profesor en la universidad.

Sin otro particular, aprovecho la oportunidad para enviarle un cordial saludo.

Atentamente

[redacted]

Dr. Irvin López García
Jefe del Área de Ingeniería Energética y Eléctromagnpetica

3 de marzo de 2015

Dra Margarita M. González Brambila
Jefa del Departamento de Energía
Presente

Estimada Doctora González,

Quiero solicitar su amable intervención para que se me conceda una prorroga dentro de la Cátedra Michael Faraday. Entiendo que de acuerdo con la legislación las Cátedras son prorrogables por un año más.

Anexo está el plan de las actividades que espero desarrollar si se concede la prorroga, también entrego un informe de las actividades que he realizado durante el periodo del 1ro de abril de 2014 a la fecha. Es mi intención continuar trabajando de forma intensa en la docencia y en la investigación que incluyo en mi plan.

En este momento, la experiencia que he tenido en la docencia me permitirá tener un mejor desempeño en las UEA que usted me asigne. Por otra parte resulta importante continuar con el desarrollo de los proyectos de investigación en que estoy involucrado y así poder lograr llegar a los resultados esperados.

Atentamente

[redacted]

Dr. Serguei Maximov
Actualmente Catedrático en la Cátedra Michael Faraday

Casa abierta al tiempo
UNIVERSIDAD AUTÓNOMA METROPOLITANA

R.F.C. UAM - 740101AR1
CANAL DE MIRAMONTES No. 3855
COL. EX - HACIENDA DE SAN JUAN DE DIOS
DELEGACIÓN TLALPAN C.P. 14387 MÉXICO, D.F.

SP-67

CONTRATO INDIVIDUAL DE TRABAJO DE PERSONAL ACADÉMICO ORDINARIO POR TIEMPO

No.

CÁTEDRA MICHAEL FARADAY

NOMBRE DEL TRABAJADOR: MAXIMOV SERGUEI
No DE EMPLEADO: 38411
NACIONALIDAD: MEXICANA
R.F.C.: MASE7212281F9
FECHA DE NACIMIENTO: AÑO 1972 MES 12 DÍA 28
EDAD: 42 AÑOS
SEXO: MASCULINO
ESTADO CIVIL: CASADO (A)
TELÉFONO (S):
DOMICILIO:

UNIDAD: AZCAPOTZALCO
DIVISIÓN: CIENCIAS BÁSICAS E INGENIERÍA
DEPARTAMENTO: ENERGÍA
ÁREA DEPARTAMENTAL:
CLASIFICACIÓN: PROFESOR
CATEGORÍA Y NIVEL: TITULAR "C" (719)
SALARIO: $ 23,748.35
TIEMPO DE DEDICACIÓN: TIEMPO COMPLETO
HORARIO: LUNES A VIERNES DE 10:00 A 18.00 HORAS
NÚMERO DE HORAS (SOLO TIEMPO PARCIAL): DE CLASE 40 HORAS DE OTRAS ACTIVIDADES ACADÉMICAS DE AYUDANTÍA

FUNCIONES A REALIZAR

DOCENCIA: IMPARTIR CURSOS DE LICENCIATURA Y POSGRADO RELACIONADOS CON COMPUTACIÓN, ELECTRICIDAD Y MAGNETISMO TALES COMO: TEORÍA ELECTROMAGNÉTICA, LABORATORIO DE ELECTROMAGNETISMO, CIRCUITOS ELÉCTRICOS I, II, III, FÍSICA IV, MÉTODOS NUMÉRICOS EN INGENIERÍA, CINEMÁTICA Y DINÁMICA DE PARTÍCULAS. DINÁMICA DEL CUERPO RÍGIDO, INTRODUCCIÓN A LA ELECTROSTÁTICA Y MAGNETOSTÁTICA, COMPLEMENTOS DE MATEMÁTICAS, MATEMÁTICAS APLICADAS A LA INGENIERÍA. CÁLCULO AVANZADO CON APLICACIONES Y DEMÁS QUE SEAN NECESARIAS. APOYAR EN PROYECTOS DE INVESTIGACIÓN CORRESPONDIENTES AL ÁREA DE INGENIERÍA ENERGÉTICA Y ELECTROMAGNÉTICA, EN PARTICULAR: ELECTROMAGNETISMO COMPUTACIONAL Y TRANSFORMADORES. INVESTIGACIÓN. PARTICIPAR EN LOS SIGUIENTES TEMAS DE INVESTIGACIÓN. 1.- CÁLCULO ANALÍTICO DE PARÁMETROS ELÉCTRICOS DE TRANSFORMADORES DE POTENCIA TIPO NÚCLEO Y ACORAZADO UTILIZANDO FUNCIONES ESPECIALES PARA ESTUDIAR SU COMPORTAMIENTO TRANSITORIO. 2.- MÉTODOS ANALÍTICOS PARA EL CÁLCULO DE IMPEDANCIAS DE TRANSFORMADORES CON NÚCLEOS FERROMAGNÉTICOS LAMINADOS DE DIFERENTES GEOMETRÍAS (CILINDRICA TOROIDAL, ETC.). 3.- CÁLCULO ANALÍTICO DE PÉRDIDAS EN LAS PAREDES DE TANQUES DE TRANSFORMADORES DE POTENCIA EN LOS CASOS DE TANQUE DE ACERO AL CARBÓN Y ACERO INOXIDABLE. 4.- MODELOS ANALÍTICOS PARA EL DIAGNÓSTICO EN LÍNEA DE TRANSFORMADORES DE POTENCIA. FORMACIÓN DE RECURSOS HUMANOS. DIRIGIR Y/O CO-DIRIGIR PROYECTOS TERMINALES DE LAS LICENCIATURAS EN INGENIERÍA ELÉCTRICA Y FÍSICA. IMPARTIR SEMINARIOS DE INVESTIGACIÓN Y/O TALLERES DIRIGIDOS A LOS PROFESORES DEL NÚCLEO BÁSICO DEL ÁREA DE INGENIERÍA ENERGÉTICA Y ELECTROMAGNÉTICA

FECHA DE INICIO DE LABORES DE ESTABLECIMIENTO DE LA RELACIÓN LABORAL: AÑO 2014 MES 04 DÍA 01
FECHA DE TERMINACIÓN DE LABORES (EN CASO DE CONTRATACIÓN POR TIEMPO DETERMINADO): AÑO 2015 MES 03 DÍA 31

MÉXICO, D.F., A 01 DE ABRIL DE 2014

DIRECTOR DE RECURSOS HUMANOS
[redacted]
LIC. DIANA ARACELI FLORES MORA
NOMBRE Y FIRMA

TRABAJADOR
[redacted]
MAXIMOV SERGUEI
NOMBRE Y FIRMA

T1 Subdirección de Personal
T2 Trabajador
T3 C.M.G.V.P.I.P.P.A.
T4 Personal Unidad

INFORME DE TRABAJO REALIZADO POR EL **DR. SERGUEI MAXIMOV** EN EL PERÍODO DEL 1 DE ABRIL DE 2014 AL 31 DE MARZO DE 2015 COMO CATEDRÁTICO EN LA CÁTEDRA MICHAEL FARADAY EN EL DEPARTAMENTO DE ENERGÍA DE LA UAM-AZCAPOTZALCO

Por medio de la presente me complace comunicarles que durante mi estancia académica como catedrático de la Cátedra Michael Faraday en el Departamento de Energía de la Universidad Autónoma Metropolitana-Unidad Azcapotzalco, que comprendió el periodo del 1 de abril de 2014 al 31 de marzo de 2015, he participado en la impartición de diferentes materias a nivel licenciatura y el desarrollo de los proyectos de investigación que resultó en total en **9 artículos publicados** en revistas indizadas y **1 artículo publicado** en un congreso internacional. Además se han enviado ya otros **2 artículos** a revistas indizadas. A continuación se listan las materias impartidas y la descripción del trabajo realizado y los artículos publicados y enviados.

Docencia:

1. **Probabilidad y Estadística** impartida en primavera de 2014, hubo 34 alumnos inscritos. 12% MB, 35% B, 20%S, 33%NA y participé en el examen de recuperación.
2. **Probabilidad y Estadística** impartida en otoño de 2014, hubo 47 alumnos inscritos. 36% MB, 32% B, 17%S, 15%NA y participé en el examen de recuperación.
3. **Teoría Electromagnética** impartida en invierno de 2015.

Descripción con detalle de los principales logros obtenidos durante el desarrollo de los proyectos:

1. Se desarrolló un nuevo y riguroso método analítico de cálculo de campos electromagnéticos y pérdidas de corrientes eddy en las paredes de tanques de transformadores en las zonas donde pasan los conductores. Esto se realizó resolviendo analíticamente las ecuaciones de Maxwell en las regiones cerca de los conductores con las condiciones de frontera respectivas y considerando la permeabilidad lineal. Como resultado se obtuvieron nuevas fórmulas analíticas para calcular el campo magnético en tres diferentes regiones y fórmula para calcular pérdidas de corrientes inducidas. Se consideraron varios casos de estudio. Los resultados se compararon con 3D simulaciones de elemento finito. La comparación mostró una excelente correspondencia entre los resultados analíticos y numéricos. Los resultados de investigación se publicaron en una revista indizada de alto factor de impacto:

S. Maximov, J. C. Olivares-Galvan, S. Magdaleno-Adame, R. Escarela-Perez, E. Campero-Littlewood, "New Analytical Formulae for Electromagnetic Field and Eddy Current Losses in Bushing Regions of Transformers." IEEE Transactions on Magnetics, DOI 10.1109/TMAG.2014.2360364.

2. Se planteó y se resolvió de manera eficiente el problema de cálculo de campo electromagnético en la región de bujías de los tanques de transformadores tomando en cuenta la permeabilidad no lineal en las paredes de tanques. Se resolvieron las ecuaciones de Maxwell no lineales respectivas usando la formulación de ecuaciones integrales que propiamente incluye las condiciones de frontera. Para resolver las ecuaciones integrales propuestas se utilizó el procedimiento iterativo. El esquema iterativo mostró una excelente convergencia numérica y baja demanda computacional comparando con los modelos no lineales de elemento finito. La comparación de los resultados de

investigación con 3D simulaciones de elemento finito mostró una excelente correspondencia para un amplio rango de corrientes en los conductores. Los resultados de investigación se publicaron en una revista indizada de alto factor de impacto:

S. Maximov, R. Escarela-Perez, S. Magdaleno-Adame, J.C. Olivares-Galvan, E. Campero-Littlewood, "Calculation of Nonlinear Electromagnetic Fields in the Steel Wall Vicinity of Transformer Bushings." IEEE Transactions on Magnetics, DOI 10.1109/TMAG.2014.2379217.

3. Se realizó un riguroso desarrollo analítico para hallar una fórmula que provee la distribución de temperatura en las zonas de tanques de transformadores de distribución, cercanas a las bujías. La ventaja de la nueva fórmula consiste en que ésta puede usar la distribución de pérdidas obtenidas tanto analítico como numéricamente. Este hecho se mostró usando dos distribuciones de pérdidas diferentes en combinación con la nueva fórmula y comparando estos resultados con simulaciones de elemento finito que usaron la distribución de pérdidas preestablecida en un caso y los resultados de la solución de un problema acoplado térmico-electromagnético en el segundo caso. Se encontró una excelente correspondencia entre los resultados numéricos y analíticos lo cual se comprobó usando las dos filosofías computacionales de manera independiente. A su vez esto claramente demostró que la fórmula propuesta es exacta y efectiva. Además la fórmula propuesta requiere de mucho menos recursos computacionales comparando que el método de elemento finito, el cual utiliza los software comerciales y de alta especialidad. Nuestra fórmula contribuirá al mejor diseño de transformadores incrementando su vida media y reduciendo sus costos en las redes eléctricas. Los resultados de investigación se enviaron a una revista indizada de alto factor de impacto y actualmente se encuentra en revisión:

S. Maximov, R. Escarela-Perez, J. C. Olivares-Galvan, J. Guzman, and E. Campero-Littlewood, "New Analytical Formula for Temperature Assessment on Transformer Tanks." Enviado a IEEE Transactions on Power Delivery el 20 de Enero de 2015.

4. De acuerdo con la configuración convencional (L-H) de devanado de transformadores de distribución, el devanado de baja tensión (LV) se encuentra internamente mientras el de alta tensión (HV) se encuentra externamente. Se propuso una nueva configuración (H-L) de devanado, según la cual la posición de devanados se intercambia, es decir, el devanado de alta tensión está situado internamente y el de baja tensión se encuentra externamente. En los diseños de transformador analizados en este trabajo, el devanado de alta tensión está fabricado con conductores de cobre y el de baja tensión con hojas de aluminio. Hemos modificado nuestro programa de diseño del transformador para analizar la nueva configuración. Se consideraron transformadores del rango de 30 a 112,5 kVA para mostrar la tendencia de reducción de costos. Las configuraciones H-L y L-H se compararon con respecto a los siguientes parámetros: longitud media el devanado del tipo HV, la longitud media de LV devanado, peso del conductor de alta tensión, peso de LV conductor, costo de la materia, y el costo total. Como resultado del cambio en el diseño propuesto, se ahorrará material en la fabricación de transformadores y se reducirá el costo. La reducción de costos es especialmente importante en el entorno de la competitividad de las empresas fabricantes de transformadoras de todo el mundo. Los resultados de esta investigación se publicaron en una revista indizada de alto factor de impacto:

Juan C. Olivares-Galvan, Rafael Escarela-Perez1, Serguei Maximov, Salvador Magdaleno-Adame and Pavlos S. Georgilakis, "Cost reduction by interchanging the location of the windings in distribution transformers with HV copper winding and LV aluminum winding." Int. Trans. Electr. Energ. Syst. (2014) DOI: 10.1002/etep.

5. Se presentó un análisis y cálculo de las pérdidas parásitas en las tapas de tanques de transformadores del tipo de núcleo trifásico de 75 MVA. Las pérdidas en la región cerca de bujias de alta tensión se estimaron utilizando 3D simulaciones de elemento finito. En la región considerada las pérdidas parásitas son altas y su reducción es importante para evitar la presencia de puntos calientes en las tapas de tanque de transformadores de potencia. En este trabajo, un inserto no magnético de acero inoxidable (SSI) de forma de L se utilizó para reducir las pérdidas parásitas en la región de las bujias de tensión terciaria (TVBS) del transformador. Las pérdidas por parásitas en la cubierta del tanque se estimaron para un nivel de sobrecarga de 30% considerando dos casos: 1) Cuando no hay SSI y 2) Cuando el SSI es considerado. La reducción de pérdidas parásitas en las cubiertas del tanque de transformadores de potencia ayuda a evitar la presencia de peligrosos puntos de alta temperatura. Estos puntos calientes pueden degradar el aceite del transformador y pueden producir una posible falla del equipo durante su funcionamiento. Los resultados de esta investigación se publicaron en memorias in extenso de un congreso internacional de estricto arbitraje:

Salvador Magdaleno-Adame, Patricia Penabad-Duran, Juan Carlos Olivares-Galvan, Serguei Maximov, R. Escarela-Perez, Eduardo Campero-Littlewood, "Reduction of Stray Losses in Tertiary Voltage Bushings in Power Transformer Tanks." XVI IEEE Autumn Meeting of Power, Electronics and Computer Science ROPEC 2014 INTERNACIONAL.

6. Los coeficientes de difusión y distribución son parámetros importantes en el diseño de sistemas de barrera utilizados en los repositorios radiactivos. Estos coeficientes se pueden determinar usando una configuración de dos reservorios, en medio de los cuales se coloca un medio poroso saturado lleno de agua estancada. Uno de los depósitos contiene una alta concentración de radioisótopos. El objetivo del trabajo era obtener una solución analítica para la concentración de todos los radioisótopos en la cadena de descomposición de una configuración de dos depósitos. La solución analítica se obtuvo tomando en cuenta los procesos de difusión y absorción. Para ello se utilizaron tales conceptos como la concentración sobrevaluada, factores de difusión y descomposición. La solución analítica obtenida para la concentración del radioisótopo se comparó con los resultados numéricos y experimentales disponibles en la literatura. La comparación mostró un excelente acuerdo entre los resultados analíticos, numéricos y experimentales. Los resultados de esta investigación se publicaron en una revista indizada de alto factor de impacto:

Juan Guzman, Serguei Maximov, Rafael Escarela-Perez, Irvin López-García, Mario Moranchel, "Analytical solution to the diffusion, sorption and decay chain equation in a saturated porous medium between two reservoirs." Journal of Environmental Radioactivity, 139 (2015) 163-170.

7. La determinación de los coeficientes de distribución y difusión en el diseño de los sistemas de contención es una tarea importante. La determinación de estos coeficientes se puede realizar por

medio de pruebas de columna. En esta investigación se halló una solución analítica de la ecuación de transporte de un contaminante en unas pruebas de columna. El transporte consiste en la difusión, advección, la descomposición y los procesos de adsorción. Se demostró analíticamente que la solución se puede factorizar en dos partes: el factor de decaimiento (que describe el fenómeno puramente de descomposición sin dispersión) y el factor de dispersión (que sólo tiene en cuenta el proceso de dispersión). Además, se demostró la invariabilidad de los factores de dispersión con respecto al parámetro de escala. Se encontró que el factor de dispersión es poco sensible al proceso de absorción si la velocidad de Darcy es alta. La solución analítica se comparó con los datos experimentales disponibles en la literatura. La comparación mostró un excelente acuerdo entre los resultados teórico y datos experimentales. Los resultados de esta investigación se enviaron a una revista indizada de alto factor de impacto:

Juan Guzman, Serguei Maximov, Rafael Escarela-Perez, Juan Carlos Olivares-Galvan, "Analytical Solution of the Diffusion, Advection, Sorption and Decay Equation in Saturated Porous Media: Column Test." Journal of Environmental Radioactivity.

8. Además durante el periodo de la cátedra se publicaron los siguientes artículos en revistas indizadas:

V. Torres, J.L. Guardado, H.F. Ruiz, S. Maximov, "Modeling and detection of high impedance faults." Electrical Power and Energy Systems 61 (2014) 163–172.

César L. Melchor-Hernández, F. Rivas-Dávalos, S. Maximov, V. Coria, Edgar L. Moreno-Goytia, "An analytical method to estimate the Weibull parameters for assessing the mean life of power equipment." Electrical Power and Energy Systems 64 (2015) 1081–1087.

V. H. Coria, S. Maximov, F. Rivas-Dávalos, C. L. Melchor, J. L. Guardado, "Analytical method for optimization of maintenance policy based on available system failure data." Reliability Engineering and System Safety135 (2015) 55–63.

J. L. Guardado, F. Rivas-Davalos, J. Torres, S. Maximov, and E.Melgoza, "An Encoding Technique for Multiobjective Evolutionary Algorithms Applied to Power Distribution System Reconfiguration." The ScientificWorld Journa, Volume 2014, Article ID 506769, 10 pages.

S. Maximov, V. Torres, H. F. Ruiz, and J. L. Guardado, "Analytical Model for High Impedance Fault Analysis in Transmission Lines." Mathematical Problems in Engineering, Volume 2014, Article ID 837496, 10 pages.

Atentamen

Dr. Serguei Maximov
Catedrático de la Cátedra Michael Faraday,
Unidad Azcapotzalco
Universidad Autónoma Metropolitana

México DF, 1 de marzo de 2015

New Analytical Formulae for Electromagnetic Field and Eddy Current Losses in Bushing Regions of Transformers

S. Maximov[1,5], J.C. Olivares-Galvan[2,3], S. Magdaleno-Adame[4], R. Escarela-Perez[2], E. Campero-Littlewood[2]

[1]Instituto Tecnologico de Morelia, Av. Tecnologico #1500, Lomas de Santiaguito, 58120, Morelia, Michoacan, Mex
[2]Universidad Autonoma Metropolitana, Azcapotzalco, 02200, Mexico D.F., Mex
[3]On sabbatical leave, University of Alberta, Edmonton, AB T6G 2V4 Canada
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This paper presents a new and rigorous analytical calculation of electromagnetic field and eddy current losses in the zones of transformer tanks where bushings are mounted. This is done by solving Maxwell's equations in the regions surrounding bushings, with the corresponding boundary conditions and considering linear permeability. Then, by solving the modified Bessel's equation the analytical formulae to calculate the magnetic field and eddy current losses in these regions are obtained and several cases are studied. The results are compared with 3D Finite Element simulations and show very close correspondence. The obtained formulae allow straightforward calculations that can help designers to select proper parameters to optimize the design of transformers. This paper can be taken as the basis for the analysis of the nonlinear permeability case.

Index Terms – **Bushing regions, Bushing conductor, Eddy current losses, Finite Element Method (FEM), Maxwell's equations, Modified Bessel's equation, Transformers**

I. INTRODUCTION

ELECTROMAGNETIC FIELDS inside transformers had been studied by several researchers [1]-[3] before the first computer appeared. Recent progress in transformers modeling and design is significant in both numerical and analytical approaches. Numerical approaches have improved the design of transformers recently [4]-[7]. They are able to accurately model the electromagnetic phenomena taking into account, among other things, complex geometries and non-linearities due to core materials. There are also researchers dedicated to find analytical solutions [8]-[12]. However, there are analyses that still require attention, since they are important in the design phase [13], in the study of transformer failures and in the modeling of complex phenomena that occur inside transformers [14]-[16]. Analytical solutions, moreover, do not present numerical instabilities or convergence problems, which could affect the accuracy of numerical algorithms.

In this paper authors propose a new analytical formulation to compute the electromagnetic field and the eddy current losses produced by currents crossing the steel tank of transformers. The current in bushing conductors, which passes through the tank wall or cover, generate alternating magnetic fields and eddy currents in it. These losses overheat the tank wall and can impact the transformer oil properties and the insulation. In order to estimate the impact of heat and take appropriate steps to reduce it, losses due to eddy currents in the tank regions near the bushing conductor have to be determined.

Since the analysis of Turowski [17], analytical formulae have been useful to solve problems of losses in transformer covers. Normally, the method to calculate eddy current losses in transformer covers is based on Poynting's theorem [17], [18] or Maxwell's equations [19]. However, all published results are approximate [17]-[19]. For example, in the first method Turowski's formula for power dissipation in tank walls implies the use of several semi-empirical parameters such as the linearization coefficient or the correction coefficient, depending on the magnetic field magnitude, the structure of the element and the type of material. There are no rigorous mathematical methods to obtain these additional parameters.

In the second method [19] results are obtained by neglecting axial electric field in the tank wall. Nevertheless, it is necessary at least to estimate this axial component to evaluate if it can be neglected and there may be situations where it is non-negligible. On the other hand, straightforward solving of Maxwell's equations is complicated in the case of nonlinear tank wall permeability. The analysis of this case is specially complicated because of the presence of different harmonics and interaction between them. In any case, as a starting point for analyzing the nonlinear case, a correct estimation of electromagnetic field in the case of linear permeability is inevitable.

In this paper, a new and meticulous analytical formulation to model the electromagnetic field and determine eddy current losses in bushing regions of transformers is presented. In section II the geometry of the model, the symmetry of the electromagnetic field and the boundary conditions in the bushing regions are discussed. In sections III to V, formulae to calculate electromagnetic fields are obtained solving Maxwell's equations in the defined regions with the corresponding boundary conditions, considering linear permeability. Analytical formulae for the electromagnetic field in steel tanks are obtained for a wide range of frequencies. In section VI low frequencies are considered in the computation of magnetic field. Section VII is dedicated to obtain formulae to estimate eddy current losses in the tank wall. In section VIII several cases are analyzed and compared with 3D Finite Element (FE) simulations in order to verify the obtained results.

Calculation of Nonlinear Electromagnetic Fields in the Steel Wall Vicinity of Transformer Bushings

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Successful analytical formulae have been previously proposed to calculate losses in tank regions of transformers assuming linear permeabilities in the analyzed boundary-valued problem. This has resulted in easy-to-implement and low-cost computational design procedures from a transformer factory economical point of view. However, designers and analysts of transformers are constantly seeking for new ways of reducing transformer losses in actual power networks with thousands of transformers. As a result, our work has been focused on proposing new analytical formulae to determine the electromagnetic field in bushing regions of transformers, taking account of the true nature of the nonlinear permeability behavior of the tank wall. This way, the nonlinear Maxwell's equations in the regions surrounding the bushings are solved using an integral equation formulation that properly includes boundary conditions. A practical iterative procedure is thus proposed to solve the resulting nonlinear equation. The iterative scheme shows excellent numerical convergence properties with a very low computational demand as compared with finite-element nonlinear models. A comparison between our analytical results against 3D finite-element simulations reveals a close match for a wide range of conductor currents. Hence, our new formulae can be used to improve the design of transformers, increasing their efficiency.

Index Terms— **Analytical methods, Bushing conductor, Electromagnetic field, Magnetization curve, nonlinear Maxwell's equations, Modified Bessel's equation, Transformer, Finite Element Method**

I. INTRODUCTION

TRANSFORMERS are essential components in distribution and power systems. Improvement of calculation methods (numerical and analytical) leads to designs that meet the demanding challenges posed by transformer industries and electric utilities. Additionally, customers require high levels of precision and reliability on calculation results for transformers. There are two types of techniques for the modeling of field problems: numerical and analytical. Numerical methods have become popular with the development of massive computing capabilities, and although they give approximate solutions, they usually provide sufficient accuracy for engineering purposes. They have recently helped to improve the design of transformers [4]-[7]. However, solving Maxwell's equations numerically is still complicated in the presence of nonlinear permeability due to the appearance of different harmonics and the interaction between them. This type of postprocessing calculation is generally difficult if the analysis of one or several harmonics is required in the steady state.

On the other hand, analytical methods are rigorous and sound, providing unique solutions that become very useful for practical design and analysis problems [1]-[3]. Particularly, analytical methods provide powerful design tools as they yield results as explicit functions of the system variables. Moreover, analytical methods to solve Maxwell's equations [8], [9] do not present numerical instabilities or convergence problems and can even be very helpful to make numerical methods more precise and less time consuming. This way, analytical methods are sought for the electromagnetic field analysis of transformers that can in turn have an important impact on the design phase [10], as well as, in the study of failures and in the modeling of complex phenomena that occur in transformers [11]-[13]. It is also possible to get insight into the electromagnetic and electric behavior of transformers from precise mathematical expressions. They allow performing short-time parametric analyses of the electromagnetic field by varying system dimensions and material properties. We provide in this work the complete analytical solution of the electromagnetic field inside transformer tank walls as a function of its thickness. To the best of our knowledge, such nonlinear solution has not been published before.

Recently, new analytical formulae for calculation of electromagnetic field and eddy current losses in the zones of transformer tanks where bushings are mounted, have been rigorously derived [14] by solving Maxwell's equations in the regions surrounding bushings, with corresponding boundary conditions and considering linear permeability. The comparison of analytical results with 3D Finite Element (FE) simulations showed very close correspondence. In this paper, the new analytical formulation to model the electromagnetic field in bushing regions of transformers is presented taking account of the nonlinear permeability of the tank wall.

The paper is organized as follows. Section I provides the formal derivation of the new analytical formulae. The geometry of the model is briefly discussed in section II. The analytical calculation of the magnetic field in a nonlinear medium also requires an analytical description of the magnetizing curve. For this purpose, an analytical magnetization curve in the form of a linear combination between a straight line and an arctangent functions is

Reduction of Stray Losses in Tertiary Voltage Bushings in Power Transformer Tanks

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***Abstract*— This paper presents an analysis and computation of stray losses in the tank cover of a 75 MVA three-phase core-type transformer. Stray losses in the region surrounding high current bushings are estimated using 3D Finite Element (FE) simulations. In the considered region the stray losses are high and its reduction is important to avoid the presence of hot spots in the tank cover of power transformer. In this paper, an L-shape non-magnetic Stainless Steel Insert (SSI) is utilized to reduce the stray losses in the region of the Tertiary Voltage Bushings (TVBs) of the transformer. Stray losses in the tank cover are estimated for a level of overload of 30% considering two cases: 1) When there is no SSI and 2) When the SSI is considered. The reduction of stray losses in the tank cover of power transformers helps to avoid the presence of dangerous high temperature spots. Hot spots can degrade the transformer oil and they can produce a potential failure of the equipment during operation.**

Keywords*— *Stray loss, tank cover, hot spot, Finite Element (FE) simulation, high current bushings, stainless steel plate, impedance boundary, power transformer

I. INTRODUCTION

Transformer design should consider avoiding the presence of hot spots in carbon steel structural parts. Low voltage cable leads produce high stray fluxes in the tank of power transformers due to the high current circulating through them. These cables are connected to bushings mounted in the tank walls or cover. High currents produce high stray fields in the vicinity of the bushing holes and this can produce high stray losses and hot spots in these parts of the tank [1]-[5]. In this paper authors analyze the case of tertiary voltage bushings placed in the tank cover.

The use of non-magnetic Stainless Steel (SS) Inserts (SSI) in the part of the tank cover where the high current bushings are mounted can be of great help to reduce stray losses and the presence of hot spots in that region. This solution has also been used to reduce stray losses in tank walls of pad-mounted distribution transformers and in the tank walls of substation transformers [6]-[8]. Different insert geometries can be used for this purpose [9].

Furthermore, distribution transformer manufacturers use non-magnetic SSI to reduce stray losses in tank walls. Inserts have been utilized in tank walls of pole-type distribution transformers, power transformers, and instrument transformers [10]-[14]. There are also manufacturers that cut slots between the bushing holes and these are filled using non-magnetic SS solder. In these cases it is difficult to define the geometry of the SSI used by different manufacturers because they normally polish the welded SSI and if the transformer tank is painted it is not possible to identify the SSI. Although almost all transformer manufacturers used SSI, in general they do not reveal information about it.

Finite element (FE) simulations are a powerful tool for the analysis and identification of stray losses in tank covers, caused by high current bushings in power transformers. In this work numerical computation of stray losses in the tank cover of a power transformer is performed. Authors analyze the use of a non-magnetic inserts in the tank cover in the region where Tertiary Voltage Bushings (TVBs) are mounted.

3D finite element (FE) simulations were performed to calculate the stray losses in the region next to the TVBs of a 75 MVA three-phase core-type transformer. The analysis is done under a 30% overload condition (97.5 MVA) with and without the SSI welded in the tank cover. Linear impedance boundaries were used to model the carbon steel of the tank and permit to compute losses in the tank cover [8]. The highest current in the analyzed transformer is in the TVBs,

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Research note

Analytical solution to the diffusion, sorption and decay chain equation in a saturated porous medium between two reservoirs

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ABSTRACT

The diffusion and distribution coefficients are important parameters in the design of barrier systems used in radioactive repositories. These coefficients can be determined using a two-reservoir configuration, where a saturated porous medium is allocated between two reservoirs filled by stagnant water. One of the reservoirs contains a high concentration of radioisotopes. The goal of this work is to obtain an analytical solution for the concentration of all radioisotopes in the decay chain of a two-reservoir configuration. The analytical solution must be obtained by taking into account the diffusion and sorption processes. Concepts such as overvalued concentration, diffusion and decay factors are employed to this end. It is analytically proven that a factor of the solution is identical for all chains (considering a time scaling factor), if certain parameters do not change. In addition, it is proven that the concentration sensitivity, due to the distribution coefficient variation, depends of the porous medium thickness, which is practically insensitive for small porous medium thicknesses. The analytical solution for the radioisotope concentration is compared with experimental and numerical results available in literature.

1. Introduction

The determination of diffusion and distribution coefficients is important in the design of barrier systems that are used in radioactive repositories. Among the available experimental setups, the two-reservoir configuration is commonly used to determine diffusion and distribution coefficients. This configuration consists of a saturated porous medium surrounded by two reservoirs; one of the reservoirs, called injective reservoir (IR), contains a high concentration of radioisotopes and the other, called diffusive reservoir (DR), is initially free of radioisotopes.

The goal of this work is to present an analytical solution for the radioisotope concentration in the two reservoir configuration. The analytical solution must be obtained by taking into account the diffusion and sorption processes. It is demonstrated that the solution has a factor that is invariant in time.

There are at least three ways of analyzing a two-reservoir configuration: a) analytical, b) experimental and c) finite element methods (FEM). Chen et al. (2012) found radioisotope concentrations and the diffusion coefficient using multi-compartment methods. Moridis (1999) obtained analytical solutions for the diffusion, sorption and decay equations of radioisotope concentrations in the Laplace domain. Guzmán et al. (2014), employed the finite element method (FEM) for determining diffusion and distribution coefficients. Lü and Ahl (2005) and Lü and Viljanen (2002) derived an analytical expression for the diffusion coefficient in the steady state. Pérez Guerrero et al. (2009, 2010) found an analytical expression for the concentration using classical integral transform techniques. An approximated analytical solution for the concentration in the diffusive reservoir is obtained in the work of Crank (1975) using a separation of variables technique. Shackelford (1991) reviews classical methods aimed at finding diffusion coefficients.

Alongside the analytical and numerical methods, experimental methods are a powerful tool for determining diffusion and

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Abbreviations: IR, Injective reservoir; DR, Diffusive reservoir; DC, Diffusion coefficient; DIC, Distribution coefficient.

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New Analytical Formula for Temperature Assessment on Transformer Tanks

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New Analytical Formula for Temperature Assessment on Transformer Tanks

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***Abstract*—A rigorous analytical development is presented to find a formula that provides the distribution temperature in the tank zones close to bushings of distribution transformers. The new formula can be fed with a loss distribution obtained either analytically or numerically. This fact is shown using two proven loss distributions, combined with our new formula, and comparing their results with finite element simulations that use a pre-established loss distribution in one case and solve a thermal-electromagnetic coupled problem in the second case. An excellent match between numerical and analytical results is found, which are independently determined using completely different computation philosophies. As a result, it is clearly shown that our proposed formula is effective and accurate. Moreover, it requires much lower computational resources as compared to finite element simulations that require commercial or highly specialized software. Our formula will contribute to the better design of transformers, increasing their useful lives and reducing operating costs in power networks.**

***Index Terms*—Transformer tanks, stray losses, analytical formula, heating, finite element method, transformer design.**

I. Introduction

POWER and distribution transformers are key elements in power systems for efficient transmission of bulk electric power. They may number thousands for typical networks around the world, making their performance crucial in proper operation of these systems. The efficiency of transformers is normally high but any improvement in their design can lead to huge reductions in the losses of the whole system when they exist in big numbers. Hence, it is very important to accurately determine the losses of transformers and their effects, such as temperature elevation, to propose engineering solutions that make transformers have longer useful lives and lower operating costs.

High current conductors passing through steel cover plates of power transformers are sources of power losses, generating undesirable thermal issues in their tanks. The minimisation of heating in bushing plates becomes an important aim at the design stage. Cost savings associated to reduction of energy losses and longer useful lives can be significant to customers and utilities. Assessment of the temperature in the steel wall of the tank, that is crossed by high current leads, is important. Therefore, the application of advanced techniques for precise estimation of temperature distributions in steel plates due to eddy current losses is of great interest.

Recent research pays special attention to the computation of the temperature distribution on transformer covers [1]–[4], transformer oil [5], transformer cores [6], [7], transformer radiators [8], toroidal transformers [9] and transformer windings [10] using FE and analytical methods. Although FE approaches are numerically powerful and sound, they require high capacity computers, as well as, sophisticated and expensive FE software when dealing with 3D geometries and very small skin depths in nonzero permeability and conductivity regions, such as those found in tanks of power and distribution transformers.

On the other hand, analytical methods provide powerful design tools as they yield explicit functions of the system geometry and input and output variables. As a result, they are very useful for practical design and analysis problems. Moreover, powerful computers or costly licences of specialised software are no longer required. This work presents an analytical method for calculating the temperature distribution on flat metallic covers by solving the governing heat conduction equation. The loss density due to electromagnetic induction is considered known and provided by any available method (analytical or numerical), decoupling the electromagnetic and temperature field problems. Analytical approaches and specific formulae for calculation of eddy current losses in steel plates, crossed by conductors carrying high currents, can be found for example in [11] or [12], where Maxwell's equations are solved assuming linear permeability. Nevertheless, reference [11] presents a more rigorous analytical calculation of the electromagnetic field and eddy current losses in the regions of transformer tanks surrounding the transformer bushings.

Summarizing, the aim of this paper is to obtain a general formula to calculate temperature distributions in transformers covers, originated by losses. The input loss stimulus of the heat equation is supplied by analytical formulae. Input stimulus coming from a numerical approach can also be readily accommodated by our new formula. Thus, our results can be considered purely analytical, conveniently compared with advanced FE simulations whose results are obtained in a completely different and independent way. Although the loss formula of [11] is more accurate than the analytical expression of [12], the later is used to obtain the input loss stimulus because of its appealing simplicity (avoiding cumbersome expresions) and satisfactory precision when dealing with not very small skin depths in the metallic plate. However, Ref.

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Abstract: The determination of the distribution and diffusion coefficients in the design of contention systems is an important task. The determination of these coefficients can be realized by means of column tests. An analytical solution to the transport equation of a contaminant in a column tests is found in this work. The transport involves the diffusion, advection, decay and sorption processes. It is analytically demonstrated that the solution can be factorized in two parts: the decay factor (which describes purely the decay phenomenon without dispersion) and the dispersive factor (which takes into account only the dispersion process). In addition, an invariance of the dispersive factors with respect to parameter scaling is shown to exist. Moreover, it is found that the dispersive factor is little sensible to the sorption process if the Darcy velocity is high. The analytical solution is compared with experimental data available in the literature.

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An analytical method to estimate the Weibull parameters for assessing the mean life of power equipment

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ABSTRACT

The two-parameter Weibull distribution is the predominant distribution for lifetime modelling of power equipment. However, the parameter estimation methods reported in the literature require numerical or graphical techniques due to the lack of a closed-form expression for the Weibull shape parameter. Therefore, in this paper, a simple, consistent, closed-form estimator based on maximum likelihood estimate for the Weibull shape parameter is proposed. The new estimator is obtained after proving the existence and uniqueness of the solution of the estimating function. In order to assess the proposed method, two right-censored data sets of two types of power equipment reported in the literature were used to apply the method for estimating the mean life, standard deviation and survival function. The results obtained were compared with the results from numerical and graphical based estimators. From this comparative analysis, it can be said that the proposed analytical parameter estimation method is more practical and efficient in the sense of closed-form expressions are used to estimate the shape and scale parameters.

Introduction

The mean life of power equipment is typically estimated via methods based on inference from historical lifetime data. The central part of statistical inference based on a distribution function is the estimation of the distribution parameters. Several statistical distributions, including two-parameter Weibull distribution [1–6], normal distribution [1], log-normal distribution [7], three-parameter Weibull distribution [8], and generalized exponential distribution [9], have been proposed for lifetime data analysis of power equipment. However, the two-parameter Weibull distribution, which is defined by the shape and scale parameters, is a commonly used model in reliability and lifetime data analysis.

The problem of estimating the shape and scale parameters of the Weibull distribution has been approached in the literature by various techniques, such as least squares, probability plotting, and maximum likelihood estimation (MLE). For the MLEs, the corresponding likelihood equations need to be solved numerically and related software programs need to be applied. For example, in [1] the author presents two methods for normal and Weibull distributions to evaluate the mean life and standard deviation of a power reactor group with limited end-of-life failure data. For the estimation of the Weibull parameters, the author developed a set of nonlinear equations using a least squares method to be solved for the scale and shape parameters by using a gradient descent method. In [2], a data-analytical method is proposed to estimate the mean life of a group of generators. In this method, the Weibull parameters are estimated by fitting a least squares regression line through the data points on a probability plot. In [3], the authors carried out an analysis of lifetime data of power transformers from an energy company in the US. They used the Weibull distribution as their lifetime model and fitted it by a direct maximization approach via the maximum likelihood and Newton–Raphson methods. In [4], a modified version of the least squares fitting method proposed in [1] is presented, where the shape parameter is estimated by using a numerical optimization software. A comparison of the parameters estimators, maximum likelihood and the median rank regression, for estimating transformer lifetime using the Weibull distribution, is presented in [5]. For the maximum likelihood estimation method, the author proposed to obtain the shape parameter by applying a numerical method, such as the Newton–Raphson. Finally, the impact of survival data on the accuracy of transformer lifetime models is analyzed in [6], where the two-parameter Weibull distribution is chosen to simulate the failure data, and the maximum likelihood estimation and the default function "wblfit" in the Matlab software are adopted to estimate the corresponding Weibull parameters.

These parameter estimation techniques proposed for modelling lifetime of power equipment have some disadvantages, which have

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A model for optimizing maintenance policy for power equipment

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ABSTRACT

Electrical utilities have the problem of applying complex mathematical models for maintenance optimization of power equipment. This is because the models presented in the literature lack the simplicity desired to carry out evaluations, and some others require a great number of input data, which may not be easily available. In order to overcome these difficulties, a new analytical optimization method for preventive maintenance (PM) policy with minimal repair at failure, periodic overhaul, and replacement is proposed for power equipment with historical failure time data influenced by a current PM policy. The method includes a new imperfect PM model based on Weibull distribution and incorporates the current overhaul interval T_0 and the optimal overhaul interval T to be found. The Weibull parameters are estimated using a new analytical method. Based on this model, the optimal number of overhauls and the optimal overhaul interval for minimizing the expected total maintenance cost are also analytically determined. Several study cases were designed in order to test the proposed model, demonstrating its applicability and simplicity to determine an optimal maintenance policy.

Introduction

Power equipment is subject to continuous wear and deterioration along its service life. Sooner or later this leads to failures, which will interrupt the normal energy supply process. The lack of proper preventive maintenance (PM) policy inevitably results in higher costs and unnecessary downtime, and although increased maintenance can effectively reduce the downtime, the associated costs will reduce utility profits. Hence, an optimal PM policy is necessary in order to ensure safety and reliability of equipment, to decrease the frequency and severity of failures, to reduce high maintenance and breakdown costs, and to improve equipment availability.

Power equipment that deteriorates with age receives along its service life preventive maintenance actions, which involves minimal repairs, periodic overhauls, and replacement actions. A minimal repair is generally carried out in order to remove a failure with minimal effort (e.g. repairing just the failed components). Since power equipment consists of many components, it is commonly assumed that minimal repairs do not change the Rate of Occurrence of Failures (ROCOF) of the equipment. Extensive research assuming minimal repairs has been conducted in [1–3]. On the other hand, an overhaul usually involves a set of preventive maintenance actions such as oil changing, cleaning, greasing, and replacing some worn components in a piece of equipment. In practice, power equipment is subject to routine or periodic overhauls, which improve its condition, but they do not return it to the state "as good as new". This is the reason why overhauls can be considered as imperfect maintenances, with the ROCOF being slightly modified by maintenance actions.

In 1995, the IEEE subcommittee on Application of Probability Methods established a task force to investigate the present status of maintenance strategies in the power industry. The results of this investigation were reported in [4]. The main conclusion of this investigation was that maintenance at fixed intervals is the most frequently used approach, and strategies based on reliability-centered maintenance (RCM) are increasingly considered for application. This can be observed recently in some applications of RCM in transmission systems [5], distribution systems [6], and wind turbines [7], just to mention a few examples. Also, other studies have proposed probabilistic maintenance models based on state diagrams. State diagrams can be directly converted into mathematical models called Markov models which can be easily solved using standard methods and analytical equations [8–11]. Other approaches have been proposed in the reliability engineering literature to model the impact of imperfect PM on the hazard rate of repairable systems (in this literature, the ROCOF is called hazard rate). These imperfect PM models can be classified into three groups [12]: age reduction models, hazard rate models, and hybrids of both. Age reduction models assume that there is an effective age reduction right after a PM action, and that the hazard

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Analytical method for optimization of maintenance policy based on available system failure data

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A B S T R A C T

An analytical optimization method for preventive maintenance (PM) policy with minimal repair at failure, periodic maintenance, and replacement is proposed for systems with historical failure time data influenced by a current PM policy. The method includes a new imperfect PM model based on Weibull distribution and incorporates the current maintenance interval T_0 and the optimal maintenance interval T to be found. The Weibull parameters are analytically estimated using maximum likelihood estimation. Based on this model, the optimal number of PM and the optimal maintenance interval for minimizing the expected cost over an infinite time horizon are also analytically determined. A number of examples are presented involving different failure time data and current maintenance intervals to analyze how the proposed analytical optimization method for periodic PM policy performances in response to changes in the distribution of the failure data and the current maintenance interval.

1. Introduction

Maintenance involves preventive and corrective actions carried out to keep physical systems in the desired operating condition or to restore them to this condition. Optimal maintenance policies aim to provide optimal system reliability/availability and safety performance at lowest possible maintenance costs. The literature on maintenance is vast. For a full overview on the state-of-the-art, the readers are referred to see [1–6].

Maintenance can be categorized into three groups: (1) corrective maintenance (CM), (2) preventive maintenance (PM) and (3) predictive maintenance (PdM). CM are actions performed when the system fails. The most common form of CM is "minimal repair", where the state of the system after repair is nearly the same as that just before failure (see [7,8]). PM is a maintenance policy based on replacing, overhauling or remanufacturing a system at fixed or adaptive time intervals, regardless of its condition at the time. The periodic PM policy can be considered as the most common maintenance policy in which a system is preventively maintained at fixed time intervals, regardless of the failure history of the system; [9–12]. PdM is an advanced preventive approach where maintenance is deferred until it is actually needed. The objective of this approach is to monitor the system in order to detect incipient faults before they can cause a part to fail [13]. This maintenance strategy has been implemented as condition based maintenance in systems where certain performance indices are periodically or continuously monitored [14–16].

PM policy has been considered by many researchers as one of the most studied maintenance policies (see [17–20]). For most industrial plants, PM is still a dominant maintenance policy as it is easy to implement and not many systems can be condition-monitored [21]. A more comprehensive definition is: PM policy is a planned maintenance that reduces or eliminates accumulated system deterioration, and is executed according with planned schedules. In the reliability and maintenance literature, PM policies are commonly classified as [22]: periodic and sequential PM.

Periodic PM is executed at integer multiples of some fixed time interval. On the other hand, sequential PM is implemented at intervals of unequal time lengths. Sequential PM is more suitable when the system requires more frequent maintenance as it ages, whereas periodic PM is more convenient to schedule. This paper addresses the problem of optimal periodic PM policy for systems with minimal repairs at failures between PM actions and replacements.

In the periodic PM policy, a system receives PM at fixed time intervals kT ($k = 1, 2, \ldots, N$), where T is the time interval between PM actions, and is replaced at the Nth PM action. It is assumed that the system receives only minimal repairs at failures occurring between PM actions, and hence, the system failure rate remains unchanged [23].

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Cost reduction by interchanging the location of the windings in distribution transformers with HV copper winding and LV aluminum winding

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SUMMARY

According to the conventional winding configuration of distribution transformers, denoted as L-H, the low voltage (LV) winding is located internally and the high voltage (HV) winding is located externally. This paper proposes a new winding configuration, denoted as H-L configuration, according to which the location of windings is interchanged, that is, the HV winding is located internally and the LV winding is located externally. In the designs of transformer analyzed in this paper, the HV winding is manufactured with copper conductors and the LV winding with aluminum sheets. We have modified our transformer design program to analyze the new H-L configuration. Transformers ratings from 30 to 112.5 kVA are considered to show the cost reduction trend. The H-L and L-H configurations are compared on the basis of the following parameters: mean length of HV winding, mean length of LV winding, weight of HV conductor, weight of LV conductor, material cost and total owning cost. As a result of the proposed design change, transformer manufacturers save material and reduce cost. Transformers cost reductions are especially important in the competitive environment of transformer companies around the world.

KEY WORDS: transformer design; cost reduction; transformer windings; L-H configuration; H-L configuration; copper; aluminum

1. INTRODUCTION

In order to successfully compete in a global economy, transformer manufacturers need to continuously improve transformer design to save material and reduce cost. Because it is easier to insulate, traditionally the low voltage (LV) winding is placed closer to the core and the high voltage (HV) winding covers the LV winding [1–23]. In this paper, this conventional arrangement of windings is called L-H configuration. Authors of [1–23] use the L-H configuration for various purposes, which are not explicitly mentioned here for the sake of space. This is a list of references that could be substantially increased, but we just want to emphasize that there is not a single publication proposing the H-L configuration. Our paper proposes a design improvement capable of reducing the distribution transformer cost while ensuring the fulfillment of all constraints in three-phase distribution transformers using rectangular windings. In this paper, the HV winding is placed closer to the core, and the LV winding covers the HV winding. This arrangement of windings is called H-L configuration. In Figure 1, we can appreciate the differences between both winding configurations.

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Research Article

An Encoding Technique for Multiobjective Evolutionary Algorithms Applied to Power Distribution System Reconfiguration

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Network reconfiguration is an alternative to reduce power losses and optimize the operation of power distribution systems. In this paper, an encoding scheme for evolutionary algorithms is proposed in order to search efficiently for the Pareto-optimal solutions during the reconfiguration of power distribution systems considering multiobjective optimization. The encoding scheme is based on the edge window decoder (EWD) technique, which was embedded in the Strength Pareto Evolutionary Algorithm 2 (SPEA2) and the Nondominated Sorting Genetic Algorithm II (NSGA II). The effectiveness of the encoding scheme was proved by solving a test problem for which the true Pareto-optimal solutions are known in advance. In order to prove the practicability of the encoding scheme, a real distribution system was used to find the near Pareto-optimal solutions for different objective functions to optimize.

1 1. Introduction

Modern societies require a complex system of generating plants, interconnected transmission lines, and distribution systems. The overall power losses in the generation, transmission, and distribution of electrical energy are estimated in 8–15% [1]. These figures mean that there is still room for reducing losses in electrical power system.

An alternative to reduce power losses in distribution systems is network reconfiguration [2]. However, this is one of the most computationally demanding problems in distribution systems because it requires the optimization of several objective functions related to the operational efficiency of distribution systems such as power losses, voltage deviations, circuit breaker operations, and expected energy not supplied, among others, while all network constraints are satisfied, for example, line currents and voltage drop limits and a radial configuration.

Considering that modern distribution system may have thousands of possible combinations of switches status, and
2 the nonlinear nature of power losses, the distribution system reconfiguration (DSR) problem can be defined as a highly complex, combinatorial, and nondifferentiable optimization problem. Furthermore, the radiality constraint introduces additional complexity to the problem, especially in large size distribution networks. Because of this, new algorithms are emerging continuously to deal with the complexity of optimizing radial power distribution system operation.

Metaheuristic algorithms using a multiobjective approach for solving the DSR problem have been very popular in the last decade [3–8], and a literature review is given in [9]. In the multiobjective approach, more than one objective function is optimized simultaneously, such as minimizing power losses and voltage deviations in the system, balancing loads in transformers, minimizing the number of operated switches during the DSR process, and maximizing system reliability. In practice, some of these objective functions are conflicting between each
other and it is not possible to find a single solution that 3
simultaneously optimizes all the objective functions, but there exists the alternative of obtaining a set of solutions, known as the Pareto-optimal solutions, which represents a tradeoff between all the conflicting objectives. Evolutionary

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Research Article

Analytical Model for High Impedance Fault Analysis in Transmission Lines

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A high impedance fault (HIF) normally occurs when an overhead power line physically breaks and falls to the ground. Such faults are difficult to detect because they often draw small currents which cannot be detected by conventional overcurrent protection. Furthermore, an electric arc accompanies HIFs, resulting in fire hazard, damage to electrical devices, and risk with human life. This paper presents an analytical model to analyze the interaction between the electric arc associated to HIFs and a transmission line. A joint analytical solution to the wave equation for a transmission line and a nonlinear equation for the arc model is presented. The analytical model is validated by means of comparisons between measured and calculated results. Several cases of study are presented which support the foundation and accuracy of the proposed model.

1. Introduction

High impedance faults are those that do not produce enough current to be detected in a reliable way by conventional devices such as relays [1]. HIF detection and localization in electrical power systems has been traditionally a challenge for protection engineers. This is due to the nature of this kind of faults, basically their variability and relatively low-current levels compared to substation load currents. Furthermore, arcing accompanies HIF, resulting in fire hazard, damage to electrical devices, and risk to human life. Under these circumstances, conventional protection relays are unable to detect and locate such faults. Though many HIFs do not involve ground at all (phase-to-phase faults due to leaning trees), phase-to-ground faults are of paramount interest because of their relevance for public safety.

This has long been recognized by the industry and since the early 70s, several methods have been proposed in the literature for HIF detection. They are based on examining different characteristics of currents and voltages in the time, frequency, and time-frequency domains. Some of these techniques are the staged fault test [2], low frequency spectrum [3], Kalman filtering [4], neural networks [5], neural networks and wavelet [6], expert systems [7], and more recently the application of harmonics analysis [8, 9], the wavelet transform [10–12], and the correlation function [13].

For HIF fault localization, techniques such as numerical algorithms [14], nonlinear frequency analysis [15], and recently, time domain studies [16] have been proposed. However, the authors consider that a complete solution to the problem of HIF detection and localization can be achieved only by a deep understanding of the interaction between the HIF and the transmission line.

In this paper, a new model to analyze the interaction between a lossless transmission line and the electric arc associated during a HIF is proposed. The transmission line is represented by the nondissipative and nondispersive wave equation and the electric arc is modelled by a Mayr-Cassie type equation. The novelty and the mathematical challenge of this problem consist in the joint solution of a linear partial differential equation, which is the wave equation, and an essentially nonlinear ordinary differential equation for the arc model. The nonlinearity of the arc phenomenon yields a general impossibility of considering the electric arc effect as load impedance in the analytic form. An elegant solution to this problem is proposed by showing that for a wide class of periodic voltages the arc phenomenon can be represented like impedance which depends on voltage

PLAN DE ACTIVIDADES PROPUESTO A REALIZAR POR EL
DR. SERGUEI MAXIMOV
EN LA PRORROGA DE LA CÁTEDRA MICHAEL FARADAY EN EL PERÍODO DEL 1 DE ABRIL DE 2015 AL 31 DE MARZO DE 2016 EN EL DEPARTAMENTO DE ENERGÍA DE LA UAM-AZCAPOTZALCO

Por medio de la presente listo a continuación mi plan de trabajo a realizar durante mi estancia académica en el Departamento de Energía de la Universidad Autónoma Metropolitana-Azcapotzalco correspondiente al periodo de 01/04/15 a 30/09/15. Durante ese periodo participaré en el desarrollo de proyectos de investigación y docencia como se detalla en el cronograma que aparece enseguida.

Docencia. Meses 1 a 12: Impartición de cursos a nivel licenciatura. Tales como: Teoría Electromagnética, Laboratorio de Electromagnetismo, Física IV, Métodos Numéricos en Ingeniería, Cinemática y Dinámica de Partículas, Dinámica de Cuerpo Rigido, Introducción a Electrostática y Magnetostática, Matemáticas Aplicadas a la Ingeniería, Cálculo Avanzado con Aplicaciones, Innovación, Retos del Desarrollo Nacional o las que la Jefatura del Departamento de Energía considere necesarias.

Mes 1 a mes 6: Deducir las ecuaciones diferenciales parciales apropiadas para resolver el problema no lineal de corrientes de remolino en conductores masivos producidas por campos magnéticos y eléctricos en sus superficies. Las soluciones se establecerán con funciones elementales y especiales y se adaptaran para crear condiciones de impedancia superficial que finalmente permitan sustituir a los conductores masivos en modelos de elementos finitos. Esto permitirá evitar la simulación explicita de conductores masivos en los modelos de elemento finito

Mes 7 a mes 12: Establecer condiciones de continuidad en las interfaces de contacto de mallas de elementos finitos incompatibles, por medio de solución analitica de ecuaciones de Maxwell en el espacio entre dos mallas con las condiciones de frontera apropiadas. Se espera utilizar diversas funciones especiales (cilíndricas, esféricas, hipergeométricas e hipergeométricas generalizadas) para la establecer dichas condiciones de continuidad

Resultados:
Al final se habrán publicado artículos donde se plasmarán los resultados obtenidos en las investigaciones realizadas.

Atentamente
[redacted]
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México DF, 1 de marzo de 2015