电网技术 2011, 35(11) 163-168 DOI: ISSN: 1000-3673 CN: 11-2410/TM

高电压技术

单芯电缆线芯温度的非线性有限元法实时计算

雷鸣1，刘刚1，邱景生1，赖育庭1，刘毅刚2，简淦杨1

1. 华南理工大学 电力学院，广东省 广州市 510640；2. 广东电网公司广州供电局，广东省 广州市 510310

摘要：

考虑电缆材料热性参数是温度的函数及忽略热量沿着线芯轴向传输所造成的线芯温度计算误差，为提高电缆线芯温度计算的精度，提出基于非线性有限单元法计算电缆导体的温度。研究电缆导体径向、轴向温度梯度以及热量扩散规律，分析运行电流、外界环境温度等因素对电缆线芯轴向、径向温度分布的影响。根据传热学原理，研究电缆热性参数随温度变化对电缆导体温度的影响，建立电缆导体温度计算三维非线性有限元模型，并通过实验数据对非线性有限元模型进行验证和修正。实验和有限元仿真的对比表明：忽略电缆热量沿着轴向传输以及热性参数的改变会造成线芯温度计算误差；所提出的电缆导体温度实时计算非线性有限元模型的有效性，为高温下运行电缆导体温度监测与负荷预测奠定了基础。

关键词： 单芯电缆 线芯温度 物性参数 非线性有限元法 实验验证 实时计算

Real-Time Core Temperature Calculation of Single-Core Cable by Nonlinear Finite Element Method

LEI Ming1, LIU Gang1, QIU Jingsheng1, LAI Yuting1, LIU Yigang2, JIAN Ganyang1

1. School of Electric Power, South China University of Technology, Guangzhou 510640, Guangdong Province, China; 2. Guanagzhou Power Bureau of Guangdong Power Grid Company, Guangzhou 510310, Guangdong Province, China

Abstract:

In IEC 60287-based computing models of cable core temperature, thermal parameters of cable materials are considered as functions of temperature and there is computational error of core temperature due to neglecting the transmission of heat along axial direction of the core. To improve the accuracy of core temperature calculation, a nonlinear finite element based method for the real-time calculation of core temperature of single-core cable is proposed. The temperature gradients of cable core conductor in axial and radial directions as well as the diffusion rule of heat quantity in cable core are researched and the influences of such factors as operating current and ambient temperature on temperature distribution of cable core in axial and radial directions are analyzed. Based on the principles of heat transfer, the influence of cable thermal parameters varying with temperature on core conductor temperature is researched and then a three-dimensional nonlinear finite element model to calculate cable core temperature is built, and the built nonlinear finite element model is validated and modified according to experimental data. Comparison of experiment data with simulation results of the proposed model shows that the calculation error of cable core temperature is caused by neglecting the transmission of heat quantity along axial direction of cable and variation of cable thermal parameters; and it is also shown that the proposed real-time cable temperature calculation model is effective and is available for reference to the monitoring of core temperature of the cable operated in high temperature environment as well as to load forecasting.

Keywords: single core cable core temperature physical parameters nonlinear finite element method experimental verification real-time calculation

收稿日期 2011-01-04 **修回日期** 2011-03-20 **网络版发布日期** 2011-11-11

DOI:

基金项目:

国家重点基础研究发展计划项目(973项目) (2009CB724507)。

通讯作者: 刘刚

作者简介:

作者Email: liugang@scut.edu.cn

参考文献：

[1] 孟凡凤，张兵，方晓明，等．影响直埋电缆载流量的因素的研究[J]．绝缘材料，2007，40(3)：64-66． Meng Fanfeng，Zhang Bing，Fang Xiaoming，et al．Study of ampacity reduction factors for burried cable[J]．Insulating Materials，2007，40(3)：64-66(in Chinese)． [2] 马国栋．电线电缆载流量[M]．北京：中国水利水电出版社，2003：148-184． [3] 李志坚，张东斐，曹慧玲，等．地下埋没电缆温度场和载流量的数值计算[J]．高电压技术，2004，30(S1)：27-30． Li Zhijian，Zhang Dongfei，Cao Huiling，et al．Numerical calculation of tenmperature field and of underground cable[J]．High Voltage Engineering，2004，30(S1)：27-30(in Chinese)． [4] 于建立，常树生，牛远方，等．地下电力电缆温度场及载流量的数值计算[J]．东北电力大学学报：自然科学版，2008，28(4)：62-65． Yu Jianli，Chang Shusheng．Niu Yuanfang，et al．Numerical simulation of thermal fields and ampacity of underground power cables [J]．Journal of Northeast Dianli University：Natural Science Edition，2008，28(4)：62-65(in Chinese)． [5] 梁永春，柴进爱，李彦明，等．基于FEM的直埋电缆载流量与外部环境关系的计算[J]．电工电能新技术，2007，26(4)：11-13． Liang Yongchun，Chai Jinai，Li Yanming，et al．Calculation of ampacity reduction factors for buried cables with surroundings based on FEM[J]．Advanced Technology of Electrical Engineering and Energy，2007，26(4)：11-13(in Chinese)． [6] 曹惠玲，王增强，李雯靖．等．坐标组合法对直埋电缆与土壤界面温度场的数值计算[J]．电工技术学报，2003，18(3)：59-63． Cao Huiling，Wang Zengqiang，Li Wenjing，et al．Numerical computation of temperature distribution of underground cables and soil with combinatorial coordinates[J]．Transactions of China Electrotechnical Society，2003，18(3)：59-63(in Chinese)． [7] 柴进爱，梁永春，李延沐，等．地下直埋发热管稳态温度场计算新方法：模拟热荷法的研究[J]．高压电器，2008，44(1)：43-46． Chai Jinai，Liang Yongchun，Li Yanmu，et al．Heat charge simulation method to calculate steady：state temperature field of underground heat pipe[J]．High Voltage Apparatus，2008，44(1)：43-46(in Chinese)． [8] 梁永春，李延沐，李彦明，等．利用模拟热荷法计算地下电缆稳态温度场[J]．中国电机工程学报，2008，28(5)：129-134． Liang Yongchun，Li Yanmu，Li Yanming，et al．Calculation of the static temperature field of underground cables using heat charge simulation method[J]．Proceeding of the CSEE，2008，28(5)：129-134(in Chinese)． [9] 成永红，谢恒，衣立东．基于热效应的电力电缆及其终端在线检测技术[J]．高电压技术，1999，25(3)：4-6． Cheng Yonghong，Xie Heng，Yi Lidong．Study on the on-line detecting technique for power cable and terminal based on heat effect[J]．High Voltage Engineering，1999，25 (3)：4-6(in Chinese)． [10] 赵建华，袁宏永，范维澄，等．基于电缆表面温度场的电缆线芯温度在线诊断研究[J]．中国电机工程学报，1999，19(1)：52-68． Zhao Jianhua，Yuan Hongyong，Fan Weicheng，et al．Surface temperature field based online diagnoses study for electric cable’s conductor temperature [J]．Proceedings of the CSEE，1999，19(1)：52-68(in Chinese)． [11] 刘毅刚，罗俊华．电缆导体温度实时计算的数学方法[J]．高电压技术，2005，31(5)：52-54． Liu Yigang，Luo Junhua．Mathematical method of temperature calculation of power cable conductor in real time[J]．High Voltage Engineering，2005，31(5)：52-54(in Chinese)． [12] 雷成华，刘刚，李钦豪．BP神经网络模型用于单芯电缆导体温度的动态计算[J]．高电压技术，2011，37(1)：184-189． Lei Chenghua，Liu Gang，Li Qinhao．Dynamic calculation of conductor temperature of single-cable using BP neural network[J]．High Voltage Engineering，2011，37(1)：184-189(in Chinese)． [13] Swift G，Molinski T S，Lehn W．A fundamental approach to transformer thermal modeling，part I：theory and equivalent circuit[J]．IEEE Trans on Power Delivery，2001，16(2)：171-175． [14] Hiranandani A，Detroit E C．Calculation of conductor temperatures and ampacities of cable systems using a generalized finite difference model [J]．IEEE Trans on Power Delivery，1991，6(1)：15-21． [15] 赵健康，雷清泉，王晓兵，等．复杂运行条件下交联电缆载流量研究[J]．高电压技术，2009，35(12)：3123-3128． Zhao Jiankang，Lei Qingquan，Wang Xiaobing，et al．Experimental research on ampacity of extruded power cable under complex operating condition[J]．High Voltage Engineering，2009，35(12)：3123-3128(in Chinese)． [16] 王俏华，顾金，吴建东，等．预处理温度对高压直流电缆附件绝缘材料空间电荷的影响[J]．电网技术，2011，35 (1)：122-126． Wang Qiaohua，Gu Jin，Wu Jiandong，et al．Influence of pretreating temperature on space charge of insulation materials for cable accessories used in HVDC transmission projects[J]．Power System Technology，2011，35(1)：122-126(in Chinese)． [17] León de F，Anders G J．Effects of backfilling on cable ampacity analyzed with the finite element method[J]．IEEE Trans on Power Delivery，2008，23(2)：537-543． [18] Tarasiewicz E，Kuffel E，Grzybowski S．Calculations of temperature distributions within cable trench backfill and the surrounding soil[J]．IEEE Trans on Apparatus and Systems，1985，3(8)：1973-1977． [19] 成永红，衣立东，程锡圭，等．运行状态下电缆终端热分布实验研究[J]．高电压技术，1996，22(3)：56-58． Cheng Yonghong，Yi Lidong，Cheng Xigui，et al．The experiment and research on thermal distribution of cable terminal in service[J]．High Voltage Engineering，1996，22(3)：56-58(in Chinese)． [20] 罗俊华，周作春，李华春，等．电力电缆线路运行温度在线检测技术应用研究[J]．高电压技术，2007，33(1)：169-172． Luo Junhua，Zhou Zuochun，Li Huachun，et al．Application of operation temperature detection technique for on-line power cable lines[J]．High Voltage Engineering，2007，33(1)：169-172(in Chinese)． [21] 曹惠玲，王增强，李文靖，等．坐标组合法对直埋电缆与土壤界面温度场的数值计算[J]．电工技术学报，2003，18(3)：59-63． Cao Huiling，Wang Zengqiang，Li Wenjing，et al．Numerical computation of temperature distribution of underground cables and soil with combinatorial coordinates[J]．Transactions of China Eletrotechnical Society，2003，18(3)：59-63(in Chinese)． [22] 梁永春，李彦明，柴进爱，等．地下电缆

群稳态温度场和载流量计算新方法[J]．电工技术学报，2007，22(8)：185-190． Liang Yongchun，Li Yanming，Chai Jinai，et al．A new method to calculate the steady-state temperature field and ampacity of underground cable system[J]．Transactions of China Electrotechnical Society，2007，22(8)：185-190(in Chinese)． [23] Anders G J．Power cable thermal analysis with considerations of heat and moisture transfer in the soil[J]．IEEE Trans on Power Delivery，1988，3(4)：1280-1285． [24] 赵建华，袁宏永，范维澄，等．基于电缆表面温度场的电缆线芯温度在线诊断研究[J]．中国电机工程学报，1999，19(11)：52-58． Zhao Jianhua，Yuan Hongyong，Fan Weicheng，et al．Surface temperature field based online diagnoses study for electric cable's conductor temperature[J]．Proceedings of the CSEE，1999，19(11)：52-58(in Chinese)． [25] 樊友兵，张丽，蒙邵新，等．中低压交联电缆集群敷设载流量的计算[J]．高电压技术，2005，31(10)：59-60． Fan Youbing，Zhang Li，Meng Shaoxin，et al．Calculation of current rating for medium and low voltage XLPE cable in custer laying[J]．High Voltage Engineering，2005，31(10)：59-60(in Chinese)．

本刊中的类似文章

1．朱宽军 邸玉贤 李新民 付东杰.架空输电线路非同期摇摆数值模拟研究[J]. 电网技术, 2009,33(20): 202-206