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电机驱动

考虑电压电流约束的感应电机容错运行对比研究

孙凯, 陈伟斌, 翟晓卉

作者信息 +

Comparative Study on Fault-tolerant Operation of Induction Motor Considering Voltage and Current Constraints

SUN Kai, CHEN Weibin, ZHAI Xiaohui

Author information +

History +

摘要

围绕电机驱动系统可靠性提高问题,对现有几种具备容错运行能力的三相感应电机驱动系统性能开展了对比研究。对容错控制策略的评估应考虑电机驱动系统输出的实际转矩和转速,而这主要取决于系统电流和电压约束。考虑到励磁电流的存在,感应电机驱动系统中的电流极限不如永磁电机驱动系统中的电流极限直观,同时逆变器和电机都存在对系统电压的限制,故通过推导故障后电机驱动系统的电压方程,分析得到了电机参数、运行工作点和电压电流约束对输出转速的影响,并指出优化拓扑可便故障后电机运行在额定转速以上以获得额外的功率。利用搭建的感应电机驱动测试平台开展了实验研究,不同容错策略的对比实验结果验证了理论分析。

Abstract

Focusing on the problem of improving the reliability of motor drive systems, a comparative study on the performance of several three-phase induction motor drive systems with fault-tolerant operation capabilities was carried out. The evaluation on the fault-tolerant control strategy should consider the actual output torque and rotation speed of the motor drive system, which mainly depends on the system current and voltage constraints. Considering the existence of excitation current, the current limit in the induction motor drive system is not as intuitive as that in the permanent magnet motor drive system. At the same time, both the inverter and motor have constraints on the system voltage, so the effects of motor parameters, operating points and voltage and current constraints on the output speed are analyzed by deducing the voltage equation for the postfault motor drive system. In addition, it is pointed out that the optimized topology can make the postfault motor run at a rotation speed higher than the rated speed to gain extra power. An experimental study was carried out on an induction motor driving test platform, and the comparative experimental results under different fault-tolerant strategies verified the theoretical analysis.

关键词

感应电机 / 故障容错控制 / 可靠性 / 约束

Key words

induction motor / fault-tolerant control / reliability / constraint

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参考文献

[1] 班东坡, 李红梅, 刘立文. 高效异步电机设计综述[J]. 微电机, 2018, 51(4): 62-68.
Ban Dongpo, Li Hongmei, Liu Liwen.Review on design and optimization of high efficient induction motor[J]. Micromotors, 2018, 51(4): 62-68 (in Chinese).
[2] 王培龙, 史黎明, 杜玉梅. 一种基于电磁耦合的储能驱动用新型双转子感应电机[J]. 中国电机工程学报, 2019, 39(17): 5216-5224, 5302.
Wang Peilong, Shi Liming, Du Yumei.A novel dual-rotor induction motor based on electromagnetic coupling applied for energy storage and driving[J]. Proceedings of the CSEE, 2019, 39(17): 5216-5224, 5302 (in Chinese).
[3] 彭思, 郑泽东, 刘自程, 等. 基于虚拟绕组和全阶观测器的五相感应电机无速度传感器容错控制策略[J]. 电工技术学报, 2018, 33(21): 4949-4961.
Peng Zhong, Zheng Zedong, Liu Zicheng, et al.A novel sensorless fault-tolerant control of five-phase induction machine using virtual winding and full-order observer[J]. Transactions of China Electrotechnical Society, 2018, 33(21): 4949-4961 (in Chinese).
[4] 袁丽丽, 慈文彦. 感应电机驱动系统的嵌入式闭环容错控制研究[J]. 电气传动, 2017, 47(11): 67-73.
Yuan Lili, Ci Wenyan.Research on embedded closed-loop fault-tolerant control for induction motor driving system[J]. Electric Drive, 2017, 47(11): 67-73 (in Chinese).
[5] De Araujo Ribeiro R L, Jacobina C B, Da Silva E R C, et al. Fault-tolerant voltage-fed PWM inverter AC motor drive systems[J]. IEEE Transactions on Industrial Electronics, 2004, 51(2): 439-446.
[6] 王庆丰, 吴俊勇, 刘自程. 一种基于谐波平面检测的五相电机驱动系统单相断相故障诊断方法[J]. 中国电机工程学报, 2019, 39(2): 417-426, 639.
Wang Qingfeng, Wu Junyong, Liu Zicheng.A single-phase open-circuit fault diagnosis method for five-phase motor drive system based on the detection of harmonic current plane[J]. Proceedings of the CSEE, 2019, 39(2): 417-426, 639 (in Chinese).
[7] 王臻, 李承, 王蕾, 等. 基于解析导纳的感应电机故障诊断[J]. 电力自动化设备, 2016, 36(8): 170-175.
Wang Zhen, Li Cheng, Wang Lei, et al.Induction generator fault diagnosis based on analytical admittance[J]. Electric Power Automation Equipment, 2016, 36(8): 170-175 (in Chinese).
[8] 孟云平, 周新秀, 李红, 等. 基于四桥臂拓扑的永磁同步电机断相容错控制策略[J]. 电工技术学报, 2019, 34(15): 3158-3166.
Meng Yunping, Zhou Xinxiu, Li Hong, et al.Fault tolerant strategy of four-leg for permanent magnet synchronous motor in case of open circuit fault[J]. Transactions of China Electrotechnical Society, 2019, 34(15): 3158-3166 (in Chinese).
[9] Garg P, Essakiappan S, Krishnamoorthy H S, et al.A fault-tolerant three-phase adjustable speed drive topology with active common-mode voltage suppression[J]. IEEE Transactions on Power Electronics, 2015, 30(5): 2828-2839.
[10] Beltrao de Rossiter Correa M, Brandao Jacobina C, Cabral da Silca E R, et al. An induction motor drive system with improved fault tolerance[J]. IEEE Transactions on Industry Applications, 2001, 37(3): 873-879.
[11] 佟诚德, 许兵, 程路明, 等. 采用六相八桥臂变流器永磁同步电机系统的驱动及容错控制仿真研究[J]. 电源学报, 2016, 14(5): 15-23.
Tong Chengde, Xu Bing, Cheng Luming, et al.Simulation of DTP-PMSM drive and fault-tolerant control system based on six-phase eight-leg VSI[J]. Journal of Power Supply, 2016, 14(5): 15-23 (in Chinese).
[12] 刘海涛, 王东, 易新强, 等. 适用于多种缺相故障的十五相感应电机统一容错控制[J]. 中国电机工程学报, 2019, 39(2): 327-336, 630.
Liu Haitao, Wang Dong, Yi Xinqiang, et al.A unified fault-tolerant control for 15-phase induction machine under various phase failure conditions[J]. Proceedings of the CSEE, 2019, 39(2): 327-336, 630 (in Chinese).
[13] 李春杰, 黄文新, 卜飞飞, 等. 具有升压和容错功能的开绕组感应电机驱动系统[J]. 电工技术学报, 2017, 32(5): 97-104.
Li Chunjie, Huang Wenxin, Bu Feifei, et al.An open-end winding induction motor driver with boost and fault-tolerant function[J]. Transactions of China Electrotechnical Society, 2017, 32(5): 97-104 (in Chinese).
[14] Sayed-Ahmed A, Mirafzal B, Demerdash N A O. Fault-tolerant technique for Δ-connected AC-motor drives[J]. IEEE Transactions on Energy Conversion, 2011, 26(2): 646-653.
[15] Liu T H, Fu J R, Lipo T A.A strategy for improving reliability of field oriented controlled induction motor drives[J]. IEEE Transactions on Industry Applications, 1993, 29(5): 910-918.
[16] Gaeta A, Scelba G, Consoli A.Modeling and control of three-phase PMSMs under open-phase fault[J]. IEEE Transactions on Industry Applications, 2013, 49(1): 74-83.
[17] 黄志坡, 周扬忠. 六相永磁同步电机缺四相容错型直接转矩控制[J]. 电力电子技术, 2017, 51(1): 78-81.
Huang Zhipo, Zhou Yangzhong.A tolerated fault direct torque control for six-phase permanent magnet synchronous motor with four opened phases[J]. Power Electronics, 2017, 51(1): 78-81 (in Chinese).
[18] 朱翀, 曾志勇, 赵荣祥. 电流品质优化的容错型三相四开关逆变器载波调制算法[J]. 电力自动化设备, 2017, 37(5): 40-47.
Zhu Chong, Zeng Zhiyong, Zhao Rongxiang.Carrier-based modulation algorithm of fault-tolerant three-phase four-switch inverter for better current performance[J]. Electric Power Automation Equipment, 2017, 37(5): 40-47 (in Chinese).
[19] 滕青芳, 李国飞, 朱建国, 等. 三相四开关容错逆变器的PMSM驱动系统FCS-MPC策略[J]. 电机与控制学报, 2016, 20(10): 15-22.
Teng Qingfang, Li Guofei, Zhu Jianguo, et al.Finite-control-set model predictive control for PMSM systems driven by three-phase four-switch fault-tolerant inverter[J]. Electric Machines and Control, 2016, 20(10): 15-22 (in Chinese).
[20] Errabelli R R, Mutschler P.Fault-tolerant voltage source inverter for permanent magnet drives[J]. IEEE Transactions on Power Electronics, 2012, 27(2): 500-508.
[21] Welchko B A, Lipo T A, Jahns T M, et al.Fault tolerant three-phase AC motor drive topologies: A comparison of features, cost, and limitations[J]. IEEE Transactions on Power Electronics, 2004, 19(4): 1108-1116.
[22] Mirafzal B.Survey of fault-tolerance techniques for three-phase voltage source inverters[J]. IEEE Transactions on In-dustrial Electronics, 2014, 61(10): 5192-5202.
[23] Naidu M, Gopalakrishnan S, Nehl T.Fault tolerant per-manent magnet motor drive topologies for automotive X-by-wire systems[J]. IEEE Transactions on Industry Applications, 2010, 46(2): 841-848.
[24] Wang W, Cheng M, Zhang B F, et al.A fault-tolerant per-manent-magnet traction module for subway applications[J]. IEEE Transactions on Power Electronics, 2014, 29(4): 1646-1658.
[25] Mendes A M S, Marques Cardoso A J. Fault-tolerant operating strategies applied to three-phase induction-motor drives[J]. IEEE Transactions on Industrial Electronics, 2006, 53(6): 1807-1817.
[26] Liu T H, Fu J R, Lipo T A.A strategy for improving reliability of field oriented controlled induction motor drives[J]. IEEE Transactions on Industry Applications, 1993, 29(5): 910-918.
[27] Wang K, Yao W X, Chen B, et al.Magnetizing curve identification for induction motors at standstill without assumption of analytical curve functions[J]. IEEE Transactions on Industrial Electronics, 2015, 62(4): 2144-2155.

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