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AC-DC变换器

LCL电压型整流器模型预测优化控制

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Model Predictive Optimal Control of LCL Voltage Source Rectifier

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摘要

传统的LCL整流器模型预测控制需要附加有源阻尼算法MPC-AD（model predictive control-active admping）来消除LCL滤波器引起的谐振问题,此时由于网侧电流由整流器侧电流间接控制,导致其控制性能不佳。为此提出了一种基于LCL滤波的电压型整流器VSR（voltage source rectifier）有限控制集模型预测优化控制策略。利用模型预测控制中多变量控制的特性,通过构建单个代价函数同时控制网侧电流矢量、滤波电容电压矢量以及整流器侧电流矢量（MPC-$i_1i_2u_C$）,无需状态变量反馈有源阻尼,然后通过所构造的代价函数来选取下一时刻最优开关状态作用于系统。为验证所提出方法的可行性,进行仿真实验并搭建测试样机。通过与传统的MPC-AD控制方法进行比较,验证了所提优化控制策略的可行性与优越性。

Abstract

The conventional model predictive control of an LCL rectifier model requires an additional active damping（MPC-AD） algorithm to eliminate the resonance problem caused by the LCL filter, which results in a poor control performance since the grid-side current is indirectly controlled by the rectifier-side current. To this end, a finite control set model predictive optimal control strategy for LCL-filtered voltage source rectifier（VSR） is proposed. The multivariable control feature of MPC is exploited, and a single cost function is constructed to simultaneously control the grid-side current vector, filter capacitor voltage vector and rectifier-side current vector（MPC-$i_1i_2u_C$）, which does not need state variables to feed back the active damping. Then, the constructed cost function J is used to select the optimal switching state that will be applied to the system at the next moment. To verify the feasibility of the proposed method, a simulation experiment was carried out and a test prototype was built. The comparison with the conventional MPC-AD control method verified the feasibility and superiority of the proposed optimal control strategy.

关键词

LCL滤波器 / 模型预测 / 有源阻尼 / 代价函数 / 多变量控制

Key words

LCL filter / model predictive / active damping / cost function / multivariable control

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参考文献

[1] Ahmed A A, Koh B K, Lee Y I.A comparison of finite control set and continuous control set model predictive control schemes for speed control of induction motors[J]. IEEE Transactions on Industrial Informatics, 2018, 14(4): 1334-1346.
[2] 魏新迟, 许利通, 骆仁松, 等. 考虑饱和效应的无刷双馈发电机功率模型预测控制[J]. 电工技术学报, 2021, 36(17): 3721-3729.
Wei Xinchi, Xu Litong, Luo Rensong, et al.Model predictive power control of brushless doubly-fed induction generator considering saturation effect[J]. Transactions of China Electrotechnical Society, 2021, 36(17): 3721-3729 (in Chinese).
[3] Nguyen H T, Kim E K, Kim I P, et al.Model predictive control with modulated optimal vector for a three-phase inverter with an LC filter[J]. IEEE Transactions on Power Electronics, 2018, 33(3): 2690-2703.
[4] 郭磊磊, 金楠, 李琰琰, 等. 电压源逆变器虚拟矢量模型预测共模电压抑制方法[J]. 电工技术学报, 2020, 35(4): 839-849.
Guo Leilei, Jin Nan, Li Yanyan, et al.Virtual vector based model predictive common-mode voltage reduction method for voltage source inverters[J]. Transactions of China Electrotechnical Society, 2020, 35(4): 839-849 (in Chinese).
[5] 夏文婧, 刘碧, 王嵩, 等. 基于输入端电压动态分量优化的PWM整流器模型预测控制[J]. 电力系统自动化, 2020, 44(1): 200-207.
Xia Wenjing, Liu Bi, Wang Song, et al.Model predictive control of PWM rectifiers based on dynamic component optimization of input-port voltage[J]. Automation of Electric Power Systems, 2020, 44(1): 200-207 (in Chinese).
[6] Li Hui, Lin Mingyao, Yin Ming, et al.Three-vector-based low-complexity model predictive direct power control strategy for PWM rectifier without voltage sensors[J]. IEEE Journal of Emerging and Selected Topics in Power Electronics, 2019, 7(1): 240-251.
[7] 柳志飞, 杜贵平, 杜发达. 有限集模型预测控制在电力电子系统中的研究现状和发展趋势[J]. 电工技术学报, 2017, 32(22): 58-69.
Liu Zhifei, Du Guiping, Du Fada.Research status and development trend of finite control set model predictive control in power electronics[J]. Transactions of China Electrotechnical Society, 2017, 32(22): 58-69 (in Chinese).
[8] Ferreira S C, Gonzatti R B, Pereira R R, et al.Finite control set model predictive control for dynamic reactive power compensation with hybrid active power filters[J]. IEEE Transactions on Industrial Electronics, 2018, 65(3): 2608-2617.
[9] Chen Xiaotao, Wu Weimin, Gao Ning, et al.Finite control set model predictive control for LCL-filtered grid-tied inverter with minimum sensors[J]. IEEE Transactions on Industrial Electronics, 2020, 67(12): 9980-9990.
[10] 阮新波, 王学华, 潘冬华. LCL型并网逆变器的控制技术[M]. 北京: 科学出版社, 2015.
Ruan Xinbo, Wang Xuehua, Pan Donghua.Control techniques for LCL-type grid-connected inverters[M]. Beijing: Science Press, 2015 (in Chinese).
[11] 李景灏, 吴爱国. 基于离散趋近律与无差拍双闭环结构的单相LCL型PWM整流器控制策略[J]. 电工技术学报, 2021, 36(6): 1290-1303.
Li Jinghao, Wu Aiguo.A double closed-loop control method for single-phase PWM rectifiers with LCL filter based on discrete reaching law and deadbeat algorithm[J]. Transactions of China Electrotechnical Society, 2021, 36(6): 1290-1303 (in Chinese).
[12] 许德志, 汪飞, 阮毅. LCL、LLCL和LLCCL滤波器无源阻尼分析[J]. 中国电机工程学报, 2015, 35(18): 4725-4735.
Xu Dezhi, Wang Fei, Ruan Yi.Passive damping of LCL, LLCL and LLCCL filters[J]. Proceedings of the CSEE, 2015, 35(18): 4725-4735 (in Chinese).
[13] 樊刚强, 杨勇. 基于LCL参数优化的新能源微电网并网逆变器控制方法[J]. 电源学报, 2021, 19(3): 70-76.
Fan Gangqiang, Yang Yong.Control method for grid-connected inverter in new energy microgrid based on LCL parameter optimization[J]. Journal of Power Supply, 2021, 19(3): 70-76 (in Chinese).
[14] Bosch S, Staiger J, Steinhart H.Predictive current control for an active power filter with LCL-filter[J]. IEEE Transactions on Industrial Electronics, 2018, 65(6): 4943-4952.
[15] Panten N, Hoffmann N, Fuchs F W.Finite control set model predictive current control for grid-connected voltage-source converters with LCL filters: a study based on different state feedbacks[J]. IEEE Transactions on Power Electronics, 2016, 31(7): 5189-5200.
[16] 张兴, 张崇巍. PWM整流器及其控制[M]. 北京: 机械工业出版社, 2003.
[17] Serpa L A, Ponnaluri S, Barbosa P M, et al.A modified direct power control strategy allowing the connection of three-phase inverters to the grid through LCL filters[J]. IEEE Transactions on Industry Applications, 2007, 43(5): 1388-1400.

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