

Adaptive Control for Shunt Active Power Filter under Stochastic Solar Photovoltaics Behavior

Surya Prakash, *Member, IEEE*, Mohamed Alkhatib, *Member, IEEE*, Hatem F. Sindi, *Senior Member, IEEE*, Sultan Alghamdi, Ranjan Kumar Behera, *Senior Member, IEEE* and Utkal Ranjan Muduli, *Senior Member, IEEE*

Abstract—The paper discusses the challenges in controlling a two-stage photovoltaic (PV)-based shunt active power filter (PV-SAPF) under distorted grid conditions and stochastic PV system behavior. To address this, the paper proposes an adaptive proportional integral (API) regulator to regulate the DC-link voltage, which adapts its parameters based on the DC-link error voltage to provide low bandwidth for disturbance rejection and high bandwidth for dynamic performance enhancement. The paper also proposes an estimation method for the reference current using the sliding discrete Fourier transform and the instantaneous symmetrical component theory, which is suitable for non-ideal grid or load conditions. The accuracy of the proposed reference current estimation method is analyzed using time- and frequency-domain analysis. The performance of the PV-SAPF system with the proposed control algorithms is illustrated through simulation and real-time hardware validation under various grid conditions. Despite distorted grid conditions, the total harmonic distortion of the grid current is substantially within IEEE Std 519-2014. The proposed API regulator and reference current estimation method show promising results in improving the performance of the PV-SAPF system in the presence of internal and external disturbances.

Index Terms—Distributed generation, instantaneous symmetrical component theory, phase-locked loop, power system harmonics, reactive power supply, shunt active power filter, sliding discrete Fourier transform.

I. INTRODUCTION

Renewable energy sources such as solar photovoltaic (PV), wind energy, and fuel cells are now being considered as potential alternatives to traditional fossil fuel-based energy sources. Compared to other renewable energy sources, solar

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PV is widely used [1]. PV panels generate direct current (DC) electricity, which requires the use of power electronics converters to connect to the conventional grid at the point of common coupling (PCC) [2]. Furthermore, charging stations for electric vehicles (EV) and variable speed drives are major applications for power electronics converters [3]. The utility grid is interconnected with these higher penetrations of power electronics devices and nonlinear loads. Since nonlinear devices draw non-sinusoidal currents from the utility, it creates serious power quality issues. This results in the AC grid being injected with undesirable harmonics. When the injected harmonics exceed a certain level, transformers, generators, motors, capacitors, and cables connected to the same utility may overheat. Hence, the injection of harmonics into the grid must be less than 5%, according to the IEEE 519-2014 [4] requirements.

This paper addresses the challenges of integrating PV-based power into the grid, which negatively affects network stability and supply quality due to the intermittent nature of solar power generation. To improve grid stability and power quality at the point of common coupling, photovoltaic systems based on the shunt active power filter (PV-SAPF) have been studied. The two-stage configurations of PV-SAPF systems offer more advantages in terms of modularity, operation, and control than single-stage architectures [1]. In a two-stage PV-SAPF system, the DC-DC converter stage increases the PV voltage, extending its working range and module flexibility. The maximum power point tracking (MPPT) scheme regulates the energy flow between the PV string and the DC-link of the inverter [5]. The perturbation and observation (P&O) based MPPT algorithm is widely used, but has limitations, which are addressed by adaptive P&O MPPT algorithms [6]. The PV-SAPF system requires an outer and inner loop controller. The outer loop controls the DC-link voltage and generates the reference current for the inner loop, which is responsible for injecting a sinusoidal current with a power factor close to unity to meet the load demand [7]–[10]. Conventional SAPF systems rely on proportional-integral (PI) controllers to regulate both fixed DC-link (FDC) and adaptive DC-link (ADC) voltages. However, the inherent characteristics of PI controllers pose limitations on disturbance rejection and dynamic response speed [11], [12]. Furthermore, ADC control may suffer from performance degradation during grid voltage sag and swell conditions. The nonlinear PI (NPI) is utilized in DC-link controllers to mitigate voltage fluctuations occur due to unbalanced non-linear load [5]. However, tuning parameters of

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Léo Pomar

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Adaptive Control of Shunt Active Power Filter Hagras Ashraf,2015-11-30 This research work proposes two new adaptive control techniques for three phase Shunt Active Power Filter SAPF Interval Type 2 Fuzzy Control IT2FC and Adaptive Backstepping Nonlinear Control ABNC The proposed methods have been compared with conventional linear and nonlinear controllers such as PI and type 1 fuzzy controllers The simulation results show that the proposed methods improve transient response and reduce THD in both line currents and voltages under the conditions of parameters uncertainties step load change and unbalanced load currents However ABNC provides better current tracking and DC voltage regulation performance than IT2FC In addition it provides robustness of performance against step change of load and frequency variations Moreover due to the adaptive nature of ABNC it is possible to work without DC voltage sensor to obtain the permissible limits of THD in line currents and voltages under the same conditions The experimental implementation proposed new current control strategy for SAPF in the stationary a b c frame This method was proven to be feasible approach for design with new version of the inverter model using Freescale DSP56F807

Power Electronics Handbook Muhammad

H. Rashid,2023-09-27 Power Electronics Handbook Fifth Edition delivers an expert guide to power electronics and their applications The book examines the foundations of power electronics power semiconductor devices and power converters before reviewing a constellation of modern applications Comprehensively updated throughout this new edition features new sections addressing current practices for renewable energy storage transmission integration and operation as well as smart grid security intelligent energy artificial intelligence and machine learning applications applied to power electronics and autonomous and electric vehicles This handbook is aimed at practitioners and researchers undertaking projects requiring specialist design analysis installation commissioning and maintenance services Provides a fully comprehensive work addressing each aspect of power electronics in painstaking depth Delivers a methodical technical presentation in over 1500 pages Includes 50 contributions prepared by leading experts Offers practical support and guidance with detailed examples and applications for lab and field experimentation Includes new technical sections on smart grid security and intelligent energy artificial intelligence and machine learning applications applied to power electronics and autonomous and electric vehicles Features new chapter level templates and a narrative progression to facilitate understanding

Microgrid

Cyberphysical Systems Bidyadhar Subudhi,Pravat Kumar Ray,2022-06-03 Microgrid Cyberphysical Systems Renewable Energy and Plug in Vehicle Integration outlines the fundamental concepts on microgrid system design and control in a cyberphysical framework focusing on the integration of renewables and EVs into microgrids Including operational control and management perspectives the volume aims to optimize the reliability and economic performance of microgrids focusing on power quality storage and voltage and frequency control The work encompasses generation transmission protection and load management under uncertainty and discusses critical drivers in robustness uncertainty and sustainability management

Focusing on applied implementations chapters are supported by detailed methods heavy figurative explication and comparative and integrative analysis Case studies range across chapters In addition chapters are supported by representative experimental or test bed validations of proposed algorithms or methods which can be directly applied to reader problems Provides advanced controller methodologies to efficiently optimize the operation of microgrids with high levels of connected renewable generators and electric vehicles Explores powerful approaches for the prevention of cyberattacks in microgrid systems Addresses design issues for power quality filters suitable for microgrid robustness uncertainty and sustainability handling Includes field tested methods heavy case studies and an implementation focus with supporting experimental or test bed validations of proposed algorithms or methods in MATLAB **Power Quality Issues** Suresh Mikkili,2018-10-08 Power Quality Issues Current Harmonics provides solutions for the mitigation of power quality problems related to harmonics Focusing on active power filters APFs due to their excellent harmonic and reactive power compensation in two wire single phase three wire three phase without neutral and four wire three phase with neutral AC power networks with nonlinear loads the text Introduces the APF technology describing various APF configurations and offering guidelines for the selection of APFs for specific application considerations Compares shunt active filter SHAF control strategies for extracting three phase reference currents evaluating their performance under a number of source voltage conditions using a proportional integral PI controller Presents PI controller based SHAF instantaneous active and reactive power p q and instantaneous active and reactive current I_d I_q control strategies supplying detailed MATLAB Simulink simulation results Proposes SHAF control strategies using type 1 and type 2 fuzzy logic controllers FLCs with different fuzzy membership functions MFs analyzing their harmonic mitigation and DC link voltage regulation Verifies the proposed type 2 FLC based SHAF control strategies with trapezoidal triangular and Gaussian fuzzy MFs using RT LAB a real time digital simulation software from OPAL RT Technologies Power Quality Issues Current Harmonics is a useful resource for those tackling electrical power quality challenges The compensation techniques described in this book alleviate harmonic issues that can distort voltage waveforms fry a building s wiring trigger nuisance tripping overheat transformer units and cause random end user equipment failure **Advancements in Automation and Control Technologies** Sarojini Selvaperumal,R. Nagarajan,P. Nedumal Pugazhenthi,2014-06-18 Selected peer reviewed papers from the 2014 International Conference on Advancements in Automation and Control ICAAC 2014 April 11 12 2014 Ramanathapuram Tamilnadu India

International Conference on Intelligent Computing and Applications M. Arun Bhaskar,Subhransu Sekhar Dash,Swagatam Das,Bijaya Ketan Panigrahi,2018-09-08 The book is a collection of best papers presented at the International Conference on Intelligent Computing and Applications ICICA 2018 held at Velammal Engineering College Chennai India on 2 3 February 2018 Presenting original work in the field of computational intelligence and power and computing technology it focuses on soft computing applications in power systems power system modeling and control FACTS devices applications in

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Automation Equipment and Systems Wen Zhe Chen,Pin Qiang Dai,Yong Lu Chen,Ding Ning Chen,Zheng Yi Jiang,2012-02-27 Selected peer reviewed papers from the 3rd international Conference on Manufacturing Science and Engineering ICMSE 2012 March 27 29 2012 Xiamen China *Proceedings of ... International Conference on Power Electronics and Drive Systems ,2005* *High Power Active Filter Systems* Subhashish Bhattacharya,2003 **IAS '98** IEEE Industry Applications Society. Meeting,1998 **International Conference on Power Control and Optimization** Nader Barsoum,Sermsak Uatrongjit,Pandian Vasant,2008-10-16 All papers have been peer reviewed The platform is the aim of this conference for all researchers engineers practitioners academicians students and industrial professionals sharing to present their research results and development activities in the area of power control and its optimization techniques We trust that the theme of the conference Innovation in power and control for optimal industry provides emulation between the researchers in their practical results as it relates to the industrial need This platform brings together researchers working on the development of techniques and methodologies to improve the performance of power system and control systems for optimal industry as well as the computational intelligent evolutionary algorithms and hybrid system optimization

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