

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 Moduli, *Senior Member, IEEE*

Abstract—The paper discusses the challenges in controlling a two-stage photovoltaic (PV)-based shunt active power filter (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

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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Surya Prakash is with the Dept. of Electrical Engg., NIT Jamshedpur, Jamshedpur, Jharkhand, India. (E-Mail: suryaprasaksh.97@nitjsu.ac.in)

Mohamed Alkhatib is with the Dept. of Electrical & Communication Engg., COE, UAE University, Al Ain, 15551, Abu Dhabi, UAE. (E-Mail: mohdalkhatib@uaeu.ac.ae)

Hatem F. Sindi and Sultan Alghamdi are with Center of Research Excellence in Renewable Energy and Power Systems, Department of Electrical and Computer Engineering, Faculty of Engineering, King Abdulaziz University, Jeddah, 21589, Saudi Arabia. (Email: hf.sindi@qu.edu.sa, email-ghamdi19@qu.edu.sa)

Ranjan Kumar Behera is with the Dept. of Electrical Engineering, Indian Institute of Technology Patna, Patna, 801 003, India. (Email: rkb@iitp.ac.in)

Utkal Ranjan Moduli is with the APEC, Dept. of Electrical Engineering and Computer Science, Khalifa University, 127788, Abu Dhabi, UAE. (Email: utkal.moduli@ku.ac.ae)

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WJ Hussar

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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 *Advanced Antenna Technologies for Aerial Platforms: From Design to Deployment*

Khalid, Saifullah, Verma, Sudhanshu, 2025-04-17 Advanced antenna technologies for aerial platforms revolutionize telecommunications defense and remote sensing increasing connectivity and data transmission capabilities As the demand for high performance communication systems in drones satellites and other airborne vehicles grows innovative designs and materials emerge to enhance antenna efficiency bandwidth and radiation patterns From the initial design phase where considerations of weight aerodynamics and environmental resilience are critical to the usage in diverse operational environments these technologies ensure reliable performance Further exploring the intricacies of advanced antenna development may allow researchers to understand how these innovations shape aerial platforms and their applications across various industries Advanced Antenna Technologies for Aerial Platforms From Design to Deployment explores the intersection of antenna technology and aerospace engineering exploring the development and application of antenna systems for communication across a broad spectrum of applications The book will encompass research on innovative antenna designs and their integration into aerospace systems including the broader potential for technological applications beyond aviation This book covers topics such as aerospace engineering manufacturing technologies and unmanned aerial vehicles and is a useful resource for business owners engineers computer scientists academicians and researchers 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 **Adaptive Control of Shunt Active Power Filter** Hagrass 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

Sustainable Energy Systems: From Primary to End-Use João Carlos de Oliveira Matias, Leonel Jorge Ribeiro Nunes, Radu Godina, 2019-09-03 This book focuses on sustainable energy systems While several innovative and alternative concepts are presented the topics of energy policy life cycle assessment thermal energy and renewable energy also play a major role Models on various temporal and geographical scales are developed to understand the conditions of technical as well as organizational change New methods of modeling which can fulfil technical and physical boundary conditions and nevertheless consider economic environmental and social aspects are also developed

Kalman Filters Ginalber Luiz Serra, 2018-02-21 This book presents recent issues on theory and practice of Kalman filters with a comprehensive treatment of a selected number of concepts techniques and advanced applications From an interdisciplinary point of view the contents from each chapter bring together an international scientific community to discuss the state of the art on Kalman filter based methodologies for adaptive distributed filtering optimal estimation dynamic prediction nonstationarity robot navigation global navigation satellite systems moving object tracking optical communication systems and active power filters among others The theoretical and methodological foundations combined with extensive experimental explanation make this book a reference suitable for students practicing engineers and researchers in sciences and engineering

Designing Control Strategies for Harmonic Power Filters to Improve the Power Quality in Distribution Networks Kumar Reddy Cheepati, T. Mariprasath, Marco Esteban Rivera Abarca, M. Nageswara Rao, 2025-06-17 In today s complex and interconnected electrical power systems maintaining high power quality is crucial for efficient operation and reliability This book delves into the intricacies of power quality issues with a special focus on harmonics and their mitigation through advanced filter design and control strategies It is tailored for both professionals and students in electrical engineering power systems and power electronics It offers a detailed exploration of the following key topics Fundamentals of power quality Understand the basic concepts of power quality its importance and the common issues encountered in modern distribution networks Harmonic analysis Learn about the sources of harmonics their effects on electrical systems and the methodologies for their analysis Filter design techniques Discover various types of harmonic filters including passive active and hybrid filters and the principles behind their design Control strategies Gain insights into advanced control techniques for harmonic filters focusing on improving system stability efficiency and performance Future trends and innovations Stay ahead with the latest developments and future trends in harmonic filtering

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Microgrid: Operation, Control, Monitoring and Protection Papia Ray, Monalisa Biswal, 2020-01-24 This book discusses various challenges and solutions in the fields of operation control design monitoring and protection of microgrids and facilitates the integration of renewable energy and distribution systems through localization of generation storage and consumption It covers five major topics relating to microgrid i e operation control design monitoring and protection The book is primarily intended for electric power and control engineering researchers who are seeking factual information but also appeals to professionals from other engineering disciplines wanting an overview of the entire field or specific information on one aspect of it Featuring practical case studies and demonstrating different root causes of large power failures it helps readers develop new concepts for mitigating blackout issues This book is a comprehensive reference resource for graduate and postgraduate students academic researchers and practicing engineers working in the fields of power system and microgrid

Hybrid Electric Vehicles and Distributed Renewable Energy Conversion: Control and Vibration Analysis Khalid, Saifullah, Ali, Javed, Yadav, Dharmendra Singh, 2024-12-10 The intersection of hybrid electric vehicles HEVs and distributed renewable energy systems represents a frontier in engineering and environmental innovation As the world moves towards sustainable energy solutions combining renewable resources such as solar and wind with HEVs offers a transformative approach to reducing carbon emissions and enhancing energy efficiency This integration not only improves the performance and sustainability of transportation but also supports decentralized energy generation allowing communities to become more energy resilient The synergy between HEVs and renewable energy systems holds significant promise in driving the global transition towards greener more sustainable infrastructures reducing dependence on fossil fuels and advancing climate goals Hybrid Electric Vehicles and Distributed Renewable Energy Conversion Control and Vibration Analysis explores the integration of HEVs and distributed renewable energy systems focusing on the control strategies and vibration analysis necessary for optimizing performance It addresses the multifaceted challenges and advancements in harnessing renewable energy sources for HEVs offering a comprehensive exploration of this dynamic field Covering topics such as artificial intelligence AI hybrid power systems and wireless charging this book is an excellent resource for researchers academicians engineers professionals graduate and postgraduate students policymakers and more

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