UNIVERSITI TEKNOLOGI MARA

ENHANCED UNIFIED POWER QUALITY CONDITIONER CONTROL MECHANISM FOR POWER QUALITY IMPROVEMENT

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ABSTRACT

Electrical power distribution quality has been significantly impacted by the widespread use of power electronic devices. Researchers have developed many dynamic and flexible solutions. Power electronics technology and fast-processing controllers have helped to introduce modern Unified Power Quality Conditioners (UPQC). UPQC is a recent Active Power Filter (APF) method for grid voltage and current-related power quality concerns. Four primary issues were discovered in this study demanding subsequent research. First, UPQCs have major inherent synchronization concerns that cannot be overcome by the conventional d-q control-based Phase-locked Loop (PLL) techniques. Nonlinear power electronic loads in the system cause power quality issues in the grid voltage, which adversely affect the performance of d-q-PLL. Second, the conventional reference current generation techniques for UPQC for solving current related power quality issues still have limitations including computational complexity, average filtration ability, and slow dynamic response. Third, the conventional reference voltage generation techniques for UPQC for solving voltage-related power quality issues are unable to reduce the system complexity because of dependency on conventional d-q-PLL and proportional-integral (PI) controllers. PI controller design needs an accurate linear mathematical model, which is difficult to develop in nonlinear and time-varying systems, making tuning for optimum gain values time-consuming. Finally, sensitive loads demand continuous power with finer power quality, yet grid voltage fluctuation, long interruptions are hindering their operation. Thus, this study focuses on three major control mechanisms that can improve the dynamic and mitigating operations of the UPQC and integrate energy storage systems to support sensitive loads. First, this work improves the d-q-PLL structure and proposes a Savitzky Golay Filter (SGF)-based PLL to solve UPQC's power quality-related synchronization issues. Next, this study enhances the conventional d-q technique and proposes an SGF-based reference current generation technique for UPQC with a simple structure, higher filtration ability, and faster dynamic response characteristics to improve UPQC performance and reduce grid current Total Harmonic Distortion (THD). Furthermore, Self-Regulated Phase estimator (SRPE)-based reference voltage generation method for UPQC is proposed that can simplify the control structure while improving dynamic responsiveness. Finally, a Photovoltaic (PV) and battery-integrated UPQC system is developed to increase its performance under poor grid conditions and support sensitive loads. In MATLAB-Simulink, the UPQC is constructed together with the respective proposed control methods, then tested considering both dynamic and steady state scenarios, and a lab prototype is created using the dSPACE microcontroller for verification reasons. From the findings, the proposed SGF-PLL in UPQC solves the synchronization issues with excellent filtration ability and faster transient response, which is within 0.07s. Next, the proposed SGF-based reference current generation method for UPQC performs outstandingly with low THD values for grid current, which is in the range of 0.82% to 3.6%, and a fast response time, which is within 0.016s to 0.022s. Furthermore, the SRPE-d-q control-based reference voltage generation method for UPQC successfully removed the necessity of two PI controllers and three voltage sensors as compared to the conventional d-q technique. Besides, UPQC is noticed to operate efficiently with low THD values for load voltage, which is 0.31% to 1.30%. Finally, the optimum performance of the PV-Battery integrated UPQC is observed when all the proposed control mechanisms are used simultaneously.

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TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Research Background

In recent times, every power distribution system must prioritize system stability and power quality (PQ) [1]. The reliability of the supply used to be customers' top priority while using energy. Today's customers, however, are more concerned with PQ than they are with supply consistency. Although distribution power systems' power quality issues are not new, customers' knowledge of them has lately grown. For many years, for instance, the majority of customers did not see disruptions that lasted less than a few minutes as a reason for worry. This has altered recently because more and more instruments are sensitive to extremely brief disruptions, and a growing number of consumers (both home and industrial) perceive brief interruptions as a significant flaw in the supply. The concept of power quality carries a crucial significance in situations when consumer expectations for high-quality electricity are on the rise. Electricity consumers are impacted by low-quality power in a variety of ways [1]. Poor PQ may result in reduction in manufacturing, damaged machinery or devices, or even be harmful to people's health. Therefore, it is crucial to preserve a high level of power quality.

PQ was essential in the past even though it has only lately become a concern. In recent times, the technology in the power electronics industry has advanced rapidly due to their high power capacities, simplicity of control and lower prices. Therefore, nonlinear loads like adjustable speed drives, welding equipment, arc furnaces, switched-mode power supplies, power converters, and so forth have become increasingly prevalent, posing serious PQ issues for the electrical grid. Besides, our contemporary civilization increasingly depends on renewable energy due to the global warming issue but integrating it into the electrical system comes with substantial PQ problems. Harmonics, transients, voltage sags/swells, distortion of the voltage or current signal, flickering, voltage unbalance, and frequency variation are all examples of PQ issues [2]. One of the primary issues with power quality is harmonic currents, which are injected by nonlinear loads and cause electronic equipment to fail, voltage quality to degrade, and transformers to overheat and lose power [3], [4]. Apart from harmonic currents, the