UNIVERSITI TEKNOLOGI MARA

INTEGRATION OF FILTER-LESS UNIFIED POWER QUALITY CONDITIONER (UPQC) CONTROL SCHEME WITH SOLAR PHOTOVOLTAIC AND BATTERY ENERGY STORAGE SYSTEM

MUHAMMAD ALIF BIN MANSOR

Thesis submitted in fulfillment
of the requirements for the degree of
Master of Science
(Electrical Engineering)

College of Engineering

July 2023

ABSTRACT

The amalgamation of existing Distribution Generation (DG) with Energy Storage Systems (ESS), Renewable Energy (RE), and Electric Vehicle to Grid (V2G) will increase concerns about power quality issues because of the present complexity of power electronic interfaces in an existing grid distribution. To ensure high power quality and reliability on the grid distribution, a unified power quality conditioner (UPQC) is a useful device for these issues. UPQC can mitigate these power quality issues by injecting appropriate voltages and currents to compensate for the disturbances in real-time, especially the harmonics penetrated by the non-linear loads. The one of most used time-domain methods in the UPQC control scheme is the synchronous reference frame (SRF). However, some drawback exists in this traditional SRF method they involve a phase lock loop (PLL) for reference signal extraction, which can cause large amplitude and phase errors and, as a result, can lead to poor voltages and currents compensation. This problem causes sluggish transient response and high overshoots, hence will impact the system stability. In this study, the proposed Filter-Less with Synchronous Reference Framework (FL-SRF) is used in the UPQC control scheme to enhance power quality at the Point of Common Coupling (PCC) under adverse voltage source problems condition (unbalanced and distorted source voltage). Fundamentally, the traditional SRF control scheme is modified with integrates the filter-less concept that had two main parts which are the phase estimator synchronization technique (FL-PES) and harmonic extractor (FL-HE). The FL-PES is used to produce the synchronization phases reference which can lead to UPQC controller generated reference current and voltage in phase with the operating power system. Therefore, in this case, a PLL necessity is omitted. This technique compared to PLL is less complex mathematical calculations, fast response, does not introduce any phase delay, and has better filtration ability. Meanwhile, the FL-HE is also used to extract the unwanted harmonic produced by the non-linear load. The suggested FL-SRF technique is compared with the traditional SRF technique by considering several case scenarios of source voltage in MATLAB-Simulink software are discussed in detail. Furthermore, the UPQC is supported by the solar Photovoltaic (PV) and Battery Energy Storage System (BESS) in this study. Generally, the PV system supplies the active power to the load. However, once the PV is unable to supply the power, then the BESS activates and provides power, especially during longer-term voltage interruption. The standalone PV system is less reliable compared to a hybrid PV-BESS system because of its instability and high environmental dependency. Results revealed that the PV-BESS-UPQC will improve the voltage support capability continuously in the longer-term grid discontinuity, reduce the complexity of the DC-link voltage regulation algorithm, keep producing clean energy, and inject power back to the grid, especially for critical loads such as semiconductor industries, hospitals, etc.

ACKNOWLEDGEMENT

In the name of Allah, The Most Merciful and The Most Gracious. Alhamdulillah, thanks to Allah S.W.T. for His blessing and guidance during the preparation of this research work and thesis.

Firstly, I wish to extend my gratitude and thankfulness to my supervisor, Dr. Muhammad Murtadha bin Othman for his continuous support, guidance, and motivation toward the completion of this research work and thesis. I feel very thankful for his assistance, patience, and thoughts during this research, he is obviously my source of encouragement to complete this work. I would also like to express my gratitude to my both co-supervisor, Professor Ir. Dr. Ismail bin Musirin and Ts. Dr. Siti Zaliha binti Mohammad Noor for his support and contribution to this work.

I would also like to record my gratitude to all my colleagues at Power and Energy with Artificial Intelligence Research Laboratory (PEARL), especially Kamrul Hasan for his support, motivation, and for being good friends.

Finally, special appreciation and gratitude to both my parents which is and for their support and prayer throughout this journey. This piece of success is dedicated to all of you. May my humble discoveries would be beneficial in this enormous world of knowledge.

Muhammad Alif bin Mansor

2023

TABLE OF CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 Research Background

The booming global energy demand is the main reason for increased fossil fuel burning and increased greenhouse gas emissions. Many researchers are working to find ways to substitute conventional fossil fuels and reduce environmental issues by encouraging the renewable generation sector. For this rationale, in recent years, the implementation and unification of Renewable Energy (RE) into the existing grid power system have grown significantly. The amalgamation of existing Distribution Generation (DG) with Energy Storage Systems (ESS) is also needed due to RE characteristics of high environment dependency, instability, and generating a small amount of power during peak time [1]. Furthermore, an advanced electrical power distribution system that uses modern communication and information technology to improve the efficiency, reliability, and sustainability of electricity delivery was introduced as a smart grid. The smart grid allows for two-way communication between the utility and the customer [2]. This capability can establish Electric Vehicle to Grid (V2G) concept to support the existing grid for a more sustainable and carbon-neutral energy system [3]. Therefore, Microgrid (MG) concept developed is composed of RE, ESS, DG, V2G, and load clusters that share the same Point of Common Coupling (PCC) that performs as a single grid. However, one of the most relevant technical challenges with functioning and handling MG systems concerns power quality issues. Power quality issues refer to the variations in voltage, current, and frequency of the electrical power supply, which can affect the performance and lifespan of electrical equipment, as well as cause disruptions in the power supply [4]. Due to the structure, operating model, and RE performance in MG, these challenges are a significant concern in the MG system. Many of the power quality issues caused by DG's high penetration include current harmonics, voltage harmonics, voltage swell or sag, fluctuation, unbalance, protective system breakdown, electrical equipment overloading, and failure [5]. This is because MG sources entirely dependent on power electronic converters, which may also extend the presence of power electronic interfaces in an existing distribution network [6]. Furthermore, energy efficiency is maintained by compensating the power quality issues which ensures a