HARMONIC MITIGATION IN DISTRIBUTION NETWORK WITH THE PRESENCE OF PV USING UNIFIED POWER QUALITY CONDITIONER

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DEDICATION

This project report is dedicated to my beloved wife, Penarsara Beevi, who encouraged and inspired me endlessly in my journey to pursue my studies in this field. Without her support and motivation, I would not have completed this work.

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ABSTRACT

The use of photovoltaic (PV) as a source of Distributed Generation (DG) or as a renewable source connected to distribution network are increasing. This type of DG is seen as an alternative future source of energy due to the depletion of conventional sources. Although they could meet the load demand, integration of those sources to the grid since the system itself contains non-linear devices and rapid usage of non-linear loads accelerating the power quality problems. Such problems are sag, dip, swell, harmonics and many more. In this report, harmonics is the key consideration and the Unified Power Quality Controller (UPQC) is proposed to mitigate the harmonics distortions. Shunt APF and Series APF in UPQC is designed in such a manner to and compensate current related and voltage related problems. This project is designed using IEEE 15 bus distribution network, rated 11kV, 60Hz and simulated by using the MATLAB/Simulink Software as a simulation tool with the presence of PV and non-linear loads. First, the harmonic distortion is generated by simulating the nonlinear loads with the Photovoltaic PV system. Then, the analysis of harmonics is carried out using Fast Fourier Transform (FFT) tool to evaluate the Total Harmonic Distortion (THD) level before and after installation of UPQC. The results from analysis showed a clear correlation between the THD % level and impact of harmonics in load flow performance. The THD % level met the IEEE standard and UPQC mitigated voltage harmonics and current harmonics by 10% and 50% respectively. The load flow analysis showed an optimal voltage profile and power efficiency is improved by using UPQC. Generally, this project was completed successfully and significantly contributes to objective.

ABSTRAK

Tenaga solar adalah tenaga boleh diperbaharui dan penggunaan tenaga ini amat sebagai menggalakkan. Tenaga dari sumber solar ini dilihat bakal menggantikan tenaga elektrik konvensional sedia ada. Namun, penggunaan sistem solar dan beban-beban tidak linear semakin meningkat dan menghasilkan kesan sampingan seperti kualiti kuasa yang rendah. Contoh kualiti kuasa yang rendah adalah voltan pusuan, voltan rendah, harmonik dan lain-lain. Projek ini adalah untuk mengkaji kesan harmonik akibat penggunaan beban tidak linear dan penambahan sistem solar ke grid. Sebuah alat penapis bernama "UPQC" digunakan untuk menapis kandungan harmonik supaya mematuhi peratutan IEEE. Alat tersebut mempunyai ciri-ciri penapis aktif siri dan ciri-ciri penapis pasif selari. Alat tersebut direka dengan teliti supaya kesan harmonic yang dihasilkan oleh beban tidak linear dan sistem solar dikurangkan kepada standard. Dalam projek ini, litar IEEE 15 bas rangkaian pengagihan bernilai 11kV, 60Hz telah digunakan. Litar tersebut disimulasi dengan perisian bernama MATLAB. Litar tersebut disambung dengan sistem solar dan beban tidak linear. Analisa dijalankan dengan menggunakan "FFT" untuk mengukur kadar harmonik dalam rangkaian sebelum dan selepas pemasangan "UPQC". Daripada analisa, didapati keputusan telah menunjukkan kadar peratusan harmonik voltan dan harmonic arus telah dikurangkan kepada 10.7% dan 50% dan menepati standard IEEE setelah menggunakan "UPQC". Analisa tersebut jugak menunjukkan "load flow" dalam rangkaian tersebut berada dalam keadaan optimum. Secara umumnya, projek ini telah berjaya dilakukan dan memberi sumbangan kepada pencapaian objektif.

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LIST OF ABBREVIATIONS

PV	-	Photo Voltaic
DER	-	Distributed Energy Resources
DC	-	Direct Current
C	-	Capacitance
L	-	Inductance
F	-	Frequency
PQ	-	Power Quality
DG	-	Distributed Generation
UPQC	-	Unified Power Quality Conditioner
FFT	-	Fast Fourier Trans
DVR	-	Dynamic Voltage Restorer
DSTATCOM	-	Distribution Static Comp
THD	-	Total Harmonic Distortion
GCPV	-	Grid Connected Photo Voltaic
MPPT	-	Maximum Power Point Tracker
PWM	-	Pulse Width Modulation
PCC	-	Point of Common Coupling

LIST OF SYMBOLS

°C	-	Celsius
Ω	-	Ohm

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Large-scale conventional generation of electricity sources are hydroelectric dams, fossil fuel fires power plants, nuclear power plants etc. These sources are in trouble due to shortage of fossil fuel, emits high CO2 emissions that pollutes the environment and losses occur in transmission line due to long distance. Currently, there comes a renewable energy sources such as wind, solar etc. Since 2000, world's power generation from solar has been growing rapidly and would continue to increase in the upcoming years. It is expected that energy would increase from 67GW in 2011 to 600GW in 2035 [1].

The harmonics magnitude and its order that produced by PV into network depend on the inverter technology. Number of power plants and its location are also contributing to harmonic distortion. Besides that, Harmonic resonance is also considered as an increasing problem due to integration between photovoltaic inverters and the grid [2]. In other way around, usage of non-linear loads is drastically increasing by end user at industrial and residential level kept growing. Rotating machines, magnetic devices, furnaces, adjustable speed drive (ASD) and power electronic switched mode power supplies are major sources of non-linear loads. Electric utility generate power with pure noise-free sinusoidal wave shape to end user [3]. However, due to heavy usage of non-linear loads and solar PV system integration into grid itself causes a pollution in electrical system or the quality of power is deteriorated.

In order to rectify the power quality issues such as harmonics, there are mitigation methods to use such as using the conventional method such as passive filter, condenser and custom power devices [4][5].

1.2 Problem statement

In today's high-tech world, most machinery used in industrial sector uses electronic operated equipment or controlled by computer. They are the main causes of poor power quality and competition among renewable energy generation especially solar are also increasing exponentially. These PQ issues result into increased power losses, abnormal and undesirable behavior of equipment's, interference with nearby communication lines, transformer derating and so forth. It is a loss for both supply provider and end user. The usage of 20% non-linear load of total load may cause harmonic contamination in network. Harmonic mitigation using conventional filters such as passive and active filter second creates drawback such as source impedance downsize the filtering capability and due to fast current response, it is difficult to build a high-capacity current source [5].

1.3 Objectives

The objectives of the project are as follows:

i. To observe the harmonic content in the distribution network due to non-linear load and PV based DG.
ii. To apply Unified Power Quality Conditioner (UPQC) in order to reduce the harmonic.
iii. To analyse the impact of UPQC on harmonics reduction.

1.4 Scopes

In this project, scopes of the project are comprising the items as below:

i. This project is to utilize a distribution network using standard IEEE 15 bus system with the integration of 100 kW of PV source and 3 phase AC Rectifier non-linear load rated Z = 60+j5.45Ω.
ii. Voltage and current harmonic Harmonics are observed in Fast Fourier Transform (FFT) analysis.
iii. The system as above is interconnected in such a way and simulated in MATLAB/Simulink.

1.5 Report Organization

This report is organized into five chapters. Chapter 1 is all about introduction, project background, problem statement, objective and scope.

In chapter 2, literature review was well explained to discuss the previous work limitations and advantages. From this review, a problem statement is established to identify the gap.

Chapter 3, the methodology part explained in detail the technique used to simulate, measure and validate the results. Basically, method is shown for before UPQC and after UPQC installation. The data measured at this part is used in analysis to discuss the consequences or contributions. Projects contribution due to improved methodology compared than the reviewed papers are shown in this part.

Chapter 4, the results from previous part is well analysed thoroughly. Discussions are clearly stated to conclude the effectiveness of methodology and to know how well the objectives are achieved. This project contribution is compared with reviewed paper and the gap are shown in this part.

Chapter 5, Conclusion and future work are states here for better understanding of the project achievements that meet the problem statement, objectives and the gap.

1.6 Significant of contribution

This project provides visible and reliable results contributed by the improved methodology used as compared in literature review especially the UPQC parameters and harmonic impact of UPQC in load flow analysis.

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