COMPARATIVE ANALYSIS OF POWER QUALITY MITIGATION IN PV ARRAY SYSTEM

ABDUL RAHIM BIN MADON

UNIVERSITI TEKNOLOGI MALAYSIA

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Specially dedicated
to my supervisor and family who encouraged
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"Allah knows your pain, sees your tears and hears your pleas".

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ABSTRACT

Renewable Energy in PV array system has gained its popularity in these days due to its user friendly approach in reducing the carbon foot print. Since the usages are also applied on the grid connected power line, it may also one of the contributors to the harmonic distortion in the power systems. There are many factors that are contributing to this issue and every root cause need to be studied and mitigated based on the analysis. The harmonic analysis in this study will be focused on the non-linear load which consists of the battery charges and UPS as the main source of the harmonic issue. Currently, there are three mitigation techniques identified for the harmonic analysis started by single tuned filter tuned at 5^{th} order, 5^{th} and 7^{th} order tuned filter and 3^{rd} order C-type filter. Once the parameters for every component are fully verified, the simulation will be conducted on the topology using ETAP software for harmonic analysis. The standard limits of IEEE 519 1992 is used as a benchmark in this study in order to provide the best output and to reduce the THDI below the limit even for some individual harmonic number and to reflect the power factor output. Based on the simulation result and projection to every mitigation technique, the 5^{th} and 7^{th} order tuned filter seems to be the most feasible approach in justifying electrical and cost. This methodology are able to reduce the THDI below the IEEE-519 standard while on the standpoint for cost and electrical advantage, the 5^{th} and 7^{th} order tuned filter is the best solution on the harmonic mitigation problem in this study since it is able to reduce the THDI effectively from 15.90% to 0.33% and improving the power factor.

ABSTRAK

Tenaga boleh diperbaharui atau tenaga solar telah meraih popularititi sebagai tenaga teknologi hijau kepada pengguna tempatan berikutan kesan negatif penggunaan bahan api konvensional yang memberi kesan langsung kepada pemanasan global. Disebabkan penggunaannya yang juga tersambung pada grid, ia juga merupakan salah satu penyumbang kepada gangguan harmonik di dalam system kuasa. Terdapat pelbagai faktor yang menyumbang kepada isu ini dan setiap punca perlu dikaji manakala langkah-langkah pangurangan perlu dibuat berdasarkan analisis. Analisa harmonik dalam kajian ini akan berfokuskan pada beban tak linear yang termasuk pengecas bateri dan sistem kuasa tak terganggu sebagai sumber utama kepada isu harmonik. Buat masa ini, terdapat tiga langkah pengurangan harmonik yang telah dikenalpasti bermula dengan penapis tunggal ditala pada perintah ke-5, penapis yang ditala pada perintah-5 dan ke-7 dan penapis jenis – C yang ditala pada perintah ke-3. Setelah semua nilai dimasukkan berdasarkan kiraaan dan disahkan, kesemua nilai akan dimasukkan ke dalam pengisian ETAP untuk teknik seterusnya bagi analisa harmonik. Piawaian yang digunakan sebagai penanda aras dalam kajian ini adalah IEEE- 519 1992 dalam mendapatkan keluaran yang terbaik dan dapat menurunkan THDI di bawah had bagi harmonik yang tertentu dan secara tidak langsung memberi faktor kuasa yang baik. Berdasarkan keputusan yang diperolehi dari simulasi untuk setiap langkah mitigasi, penapis yang ditala pada perintah-5 dan ke-7 dipilih sebagai teknik yang terbaik dari segi faedah kos dan elektrik. Teknik ini mampu mengurangkan THDI daripada 15.90% kepada 0.33% di bawah piawaian IEEE-519 secara berkesan dan dapat memperbetulkan faktor kuasa.

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LIST OF ABBREVIATIONS

PCC	-	Point of Common Coupling
EMS	-	Energy Management System
PV	-	Photovoltaic
AC	-	Alternating Current
DC	-	Direct current
PWM	-	Pulse Width Modulation
IGBT	-	Insulated Gate Bipolar Transistor

LIST OF SYMBOLS

E	-	Energy
N	-	Number of parameter
P	-	Power
L	-	Load
I	-	Current
V	-	Voltage
T	-	Period
t	-	Time
%	-	Percentages
Vo	-	Output voltage
Vs	-	Voltage supply

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Harmonics are one of the main issue in power line that presence due to the application of power electronics in everyday life which directly reflect to the increased in the magnitude. In the renewable energy supply, harmonics are also one of the criteria that need to be taken into account; particularly in the PV array system. Harmonics are mainly generated by the non-linear load such as IT load, UPS, adjustable speed drives and etc. The mechanism on how harmonics exists is by draw current in the form of nature or a reversal phenomenon like wave. Risk of interference can become severe if the total harmonics generated are not contained within the standard limit by IEC and IEEE 519 standard. Severe level of harmonics might shortened the life span of electrical devices which directly causes an overheating on the motor windings, damage section on the neutral line due to the overheating effects, line voltage imbalances, overheating failure and transformer distribution failure . For major distorting load, consumers are encouraged to install a harmonic filter in order to avoid and to mitigate the harmonic interference from entering the building supply.

Therefore, studies on the harmonics in the PV Array will provide the path and the methodology in the harmonics mitigation aligned with the new approach of modern harmonic source are obviously required. There are a few approaches in reducing the harmonic distortions and it all subjected to the budget constraint and the feasibility studies on the type of load along with the load profile analysis. The most common mitigation steps been used all these years are the line reactor, passive or active filters as well as phase shifting transformer. However, the method stated above are not perfectly suitable since every aspect of operations need to be taken into account started by the type of load, coordination of the filter and absolutely on the cost itself.

1.2 Problem Statement

Harmonics mitigation in the PV array system sharing more or less in terms of characteristics like the normal power transmission line which directly reflect that the techniques available in the market can be applied in the mitigation techniques. The available solution in the market such as k-factor transformers, Phase shifting transformers, line reactor, 12 & 18 pulse rectifiers, tune harmonic filters, based fast switched harmonic filters and active harmonic filters. Among all techniques stated just now, currently there are no single solutions for mitigation universally since everything needs to be tested and compared in the economic and electrical benefits standpoint. When it comes to mitigation, it is also important to have an analysis on the criteria based on the below requirements:-

- Compactness; where it analyses which solution provides the least space;
- Simplicity; where it identifies solution that are easiest to operate;
- THDI-mitigation for current and voltage distortion comparison;
- Efficiency; where every level of the solutions will be discussed; and
- Value for money.

1.3 Objectives of Project

In this project, target and objective need to be achieved. The main target for this project is to conduct mitigation in the PV Array systems in order to fulfil the below objectives:-

1. To conduct due diligence on the various harmonic problems generated in the PV Array system and provide comprehensive steps with the different mitigation techniques used to solve the issue;

2. To provide some analysis and comparison in the harmonic mitigation techniques; and

3. To provide the best recommendation from single to multiple harmonic mitigation techniques as the ultimate solution.

1.4 Scope of Project

This project is dedicated to implement a model or system that enables to analyse and mitigate on the power quality spectrum in PV array.

The main topology consists of integration of PV array, wind turbine and battery where the associated power quality problems will be narrowed down on the PV array in aiming for stable power delivery to the user end. The multiple alternative energies will be simulated in ETAP and the result from the PV Array portion will be studied and analysed in order to provide the most justifiable and economic output based on the proper mitigation techniques.

1.5 Project Report Outline

This thesis is complemented with 5 chapters. Chapter 1 is the background description with sequence by the problem statement which explains the objectives and scope of the study.

The next chapter will enlighten on the literature review which scrutinized on the harmonic phenomenon which narrow down from disturbance, effects and to the mitigation as solution based on the standardize harmonic distortion.

Earlier in chapter 3, the topology under study will be analysed via ETAP From the analysis, each parameter will be extracted such as THDI, THDV, power factor and load current. Once the information are carefully verified, the steps of sizing and calculating in providing mitigation techniques will be provided in details from the base case system analysis.

Chapter 4 enlightened on the results gained from all the mitigation techniques performed in the simulation. The result comprises the power factor improvement and reduction in harmonic distortion. The best mitigation techniques will be identified during this phase.

Conclusion and recommendation for future studies will be discuss further in chapter 5.

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