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ANALYZING PERFORMANCE OF SUPER-CAPACITOR AND BATTERY IN LOW VOLTAGE ELECTRICAL DISTRIBUTION SYSTEMS

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Master of Electrical Engineering

(Industrial Power)

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ANALYZING PERFORMANCE OF SUPER-CAPACITOR AND BATTERY IN LOW VOLTAGE ELECTRICAL DISTRIBUTION SYSTEMS

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A dissertation submitted
in partial fulfillment of the requirements for the degree of Master of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

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DECLARATION

I declare that this dissertation entitled "Analyzing Performance of Super-Capacitor and Battery in Low Voltage Electrical Distribution Systems" is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

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ABSTRACT

This dissertation presents a comparative study of two types of energy storage comprising of a super capacitor and a battery for reduction of harmonics in the inverter output. This dissertation deals with design and simulation of a three phase inverter in MATLAB/ SIMULINK environment and Graphical User Interface (GUI). The proposed system is designed using MATLAB/SIMULINK and it consists of a super capacitor and a battery as energy storage, Voltage Source Inverter (VSI) and filtering scheme. The controller is based on the synchronous d-q reference frame technique specifically applied to the three phase inverter and the Phase Lock Loop (PLL) is used for synchronization between grid connected voltage and inverter voltage. The design of low pass filter at the inverter output meant to remove the high frequency ripple is also discussed. The various performances of simulation results between the super capacitor and the battery have been investigated. The Total Harmonic Distortion (THD) of the inverter output voltage is measured for the two types of energy storages applied to the inverter input. All simulation results are controlled and interfaced by using GUI. It can be observed that the THD voltage for the super capacitor is considerably lower than that of the battery.

ABSTRAK

Disertasi ini membentangkan satu kajian perbandingan dua jenis storan tenaga yang terdiri daripada kapasitor super dan bateri untuk mengurangkan harmonik dalam output penyongsang. Disertasi Ini berhubung dengan reka bentuk dan simulasi penyongsang tiga fasa dalam MATLAB persekitaran / SIMULINK dan grafik Antara Muka Pengguna (GUI). Sistem yang dicadangkan ini direka menggunakan MATLAB / SIMULINK dan ia terdiri daripada kapasitor super dan bateri sebagai penyimpanan tenaga, Voltali Inverter (VSI) dan skim penapisan. Pengawal ini adalah berdasarkan kepada rujukan DQ bingkai teknik segerak khusus digunakan untuk penyongsang tiga fasa dan Fasa Kunci Loop (PLL) digunakan untuk penyegerakan antara grid yang berkaitan voltan dan voltan penyongsang. Reka bentuk penapis lulus rendah pada keluaran penyongsang bertujuan untuk mengeluarkan riak permintaan yang tinggi juga dibincangkan. Pelbagai persembahan daripada keputusan simulasi antara kapasitor super dan bateri telah disiasat . Jumlah Harmonik Penyelewengan (THD) daripada voltan keluaran penyongsang diukur untuk kedua-dua jenis penyimpanan tenaga yang digunakan untuk input penyongsang. Semua keputusan simulasi dikawal dan diantaramukakan dengan menggunakan GUI. Ia boleh diperhatikan bahawa voltan THD untu
Kapasitor super adalah jauh lebih rendah daripada bateri.

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DEDICATION

I dedicate my dissertation work to my family and many friends. A special feeling of gratitude to my loving parents and wife, whose words of encouragement and push for tenacity ring in my ears.

I also dedicate this dissertation to my many friends who have supported me throughout the process. I will always appreciate all they have done,

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LIST OF ABBREVIATIONS

AC	-	Alternating Current
DC	-	Direct Current
TLI	-	Two Levels Inverter
MLI	-	Multilevel Inverters
SC	-	Super capacitor
THD	-	Total Harmonic Distortion
THDv	-	Voltage Total Harmonic Distortion
VSI	-	Voltage Source Inverter
EC	-	Electrochemical Capacitor
EDLC	-	Electrochemical Double-Layer Capacitor
Li-Ion	-	Lithium Ion
NiMH	-	Nickel Metal Hydride
ESR	-	Equivalent Series Resistance
ODE	-	Ordinary Differential Equation
GUI	-	Graphic User Interface
ESS	-	Energy Storage System
MOSFET	-	Metaloxidesemiconductor Field-Effect Transistor
IGBT	-	Insulated Gate Bipolar Transistor
PWM	-	Pulse Width Modulation

PLL	-	Phased Locked Loop
PI	-	Proportional Integral

LIST OF SYMBOLS

P - Power, [W]

U, u - Voltage, [V]

I, I - Current, [A]

t - Time, [s]

T - Temperature, [°C]

R - Resistance, [Ω]

L - Inductance, [H]

C - Capacitance, [F]

E - Energy, [J]

Q - Charge, [C]

ΔQ - Charge difference, [C]

ΔV - Voltage difference, [V]

Rs - Series Resistance, [Ω]

Rl - Leakage Resistance, [Ω]

A - Area, [m^2]

C_{diff} - Differential Capacitance, [F]

Capacity [Ah]

D - Duty cycle/Duty Ratio [-]

E - Electric field strength, [N/C]

f_s	-	Switching Frequency, [Hz]
I	-	Current, [A]
I_{batt}	-	Battery Current, [A]
I_{sc}, I_c	-	Battery Current, [A]
I_o, I_{load}	-	Load Current, [A]
L	-	Inductance, [H]
K_i	-	Integral Gain
K_p	-	Proportional Gain
P	-	Power, [W]
V_{batt}, V_b	-	Voltage Battery, [V]
V_{sc}, V_c	-	Voltage Super capacitor, [V]
W	-	Energy [J], [Wh]

CHAPTER 1

INTRODUCTION

1.1 Background

The development of power electronics and increased powers involved and the flexibility of the use of semiconductors has electricians encouraged to undertake significant associations of static converters power to electric machines. These devices are generally non-recurring charges linear, absorbing non-sinusoidal current and behave as harmonic generators. Moreover, they sometimes consume reactive power. Therefore, the waveform of the current sinusoidal source loses and gets also a deterioration of the power factor. Therefore, the electric power distributors obliged to impose standards and be protected against these disturbances (Smith, Ieee, Sen, & Ieee, 2008). The term harmonics can be defined as how pure the voltage is, how pure the current waveform is in its sinusoidal form. The objective of the electric power distributor is to provide its customers with electricity good quality. The ideal voltage waveform used in power systems is a sine wave amplitude and constant frequency. In practice, the transmission of electricity and the use that is made user cause deformation of the sinusoid. This deformation or distortion the wave is called harmonic disturbance. The harmonic distortion is due in large part to the development of new uses (powered by electronic equipment) that spread both in industry and in households. The need for harmonic studies was crucial when energy storage system like battery and super capacitor are applied.

When identifying the effects harmonics on the network elements and the quality of service, the effects could include: additional heating of the machine, the breakdown of the capacitor, the occurrence of different resonances and harmonics in telephone sounds, etc.

This dissertation shows a comparative study of two types energy storage comprises of super capacitor and battery for reduction of the harmonic in the inverter output the effects of harmonics at both energy storages systems are discussed and all results are displayed. Furthermore, method used to control the output voltage is based on synchronous dq reference frame technique that was applied to the three phase inverter systems. In this study, the proposed strategy control applied to a three-phase inverter is Proportional Integral (PI) voltage regulator using abc to dq and dq to abc transformations. In addition, Phase Lock Loop (PLL) is used for synchronization between grid connected voltage and inverter voltage. The design of low pass filter is used at the inverter output in order to remove the high frequency ripple.

An important part of the electric system is energy storage. One alternative that has been analyzed beside battery and it provides some advantages are the super capacitor. One of super capacitors advantage is its high power density compared to batteries. It is starting to become more frequently used as energy storage for various types of systems. Moreover, the main objective of the power system would be generation of electrical energy to the end user. Also, associated with power system generation is the term power quality. So much emphasis has been given to power quality that it is considered as a separate area of power engineering.

In contrast harmonics in sources are nowadays a major concern for producers and distributors of electricity as they are found in different areas of human activity. These polluters electric power systems tend to increase due to the use of non-linear loads, include the list is not exhaustive, industrial installations using semiconductor power (the power rectifiers in particular), micro-computers, printers, scanners or other electronic devices that have low power. This phenomenon is not new, has grown in recent decades with the rapid development experienced by the power electronics and computing. We know that the resulting harmonic injection in an electric network is not a simple algebraic addition but rather a sum vector, then we say that these harmonics abound. Added to this is the "random" nature of the back-up of different receivers in a grid. They do not all work together. When designing a new system it is necessary to create a model of that system in order to test if it will work using computer simulations. Since the super capacitor is still a rather new component, the development of appropriate models is still a subject which is being investigated.

1.2 Problem Statement

Harmonics are one of the major concerns in a power system. Harmonics cause distortion in current and voltage waveforms resulting into deterioration of the power system. The first step for harmonic analysis is the harmonics from non-linear loads. The results of such analysis are complex. Over many years, battery is considered as a main storage for many applications in power systems. However, there are many disadvantages associated with batteries such as high total harmonic distortion for voltage once been introduced in low voltage distribution system.

Recently super capacitor has matured significantly over the last decade and emerged with the potential to facilitate major advances in energy storage such as high power density compared to battery. Basically, it is crucial to have low harmonics deficiencies of both energy