SWITCHED-CAPACITOR BASED MULTILEVEL INVERTER FOR RENEWABLE ENERGY SYSTEM

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DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

In recent years, the design of multilevel inverter topologies has become an important research field for researchers to further enhance the effectiveness of inverter systems due to the increased availability of renewable energy sources, for instance, PV systems. The multilevel inverter has an important feature that can improve output waveform quality. The main idea is to utilize a simple circuit technique called switched-capacitor with pulse width modulation PWM control technique so that multilevel voltage can be realized across a capacitor. The switched-capacitor design cell is connected in a series-parallel configuration to obtain voltage multiplication and charge the capacitor. Simultaneously, it can boost the output voltage two times without a DC-DC converter with the least number of components used, thus decreasing complexity for the design and reducing the costs. The proposed inverter (with integrated switched-capacitor multilevel inverter technique) can generate a line-frequency with five levels near sinusoidal AC output voltage using only six switches, using one DC voltage source only. The simulation is performed in MATLAB/Simulink. The results show that the proposed multilevel inverter works correctly to produce a minimum number of switches and five-level waveforms for the multilevel output waveform.

ABSTRAK

Dalam beberapa tahun kebelakangan ini, penyongsang bertingka topologi inverter bertingkat telah menjadi bidang penyelidikan penting bagi para penyelidik untuk meningkatkan lagi keberkesanan sistem penyongsang kerana peningkatan ketersediaan sumber tenaga yang boleh diperbaharui, misalnya, sistem PV. Penyongsang bertingka mempunyai ciri penting yang dapat meningkatkan kualiti bentuk gelombang output. Idea utamanya adalah menggunakan teknik litar sederhana yang disebut suis-kapasitor dengan teknik kawalan PWM modulasi lebar nadi supaya voltan bertingka dapat direalisasikan melintasi sebuah kapasitor. Suis-kapasitor beralih dihubungkan dalam konfigurasi selari-siri untuk mendapatkan pendaraban voltan dan mengecas kapasitor. Pada masa yang sama, ia dapat meningkatkan voltan keluaran dua kali tanpa penukar DC-DC dengan jumlah komponen yang paling sedikit digunakan, sehingga mengurangkan kerumitan untuk reka bentuk dan mengurangkan biaya. Inverter yang dicadangkan (dengan teknik penyongsang bertingkat suis-kapasitor bersepadu) dapat menghasilkan frekuensi garis dengan lima tahap berhampiran voltan keluaran AC sinusoidal dengan hanya menggunakan enam suis, menggunakan satu sumber voltan DC sahaja. Simulasi dilakukan dalam MATLAB / Simulink. Hasilnya menunjukkan bahawa inverter bertingkat yang dicadangkan berfungsi dengan betul untuk menghasilkan bilangan suis minimum dan bentuk gelombang lima tingkat untuk bentuk gelombang keluaran bertingkat.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

MLI	-	Multilevel Inverter
SC	-	Switched-Capacitor Multilevel Inverter
SCMLI		Switched-Capacitor
DC	-	Direct current
AC	-	Alternating current
PV	-	photovoltaic
NPC	-	Neutral-Point Clamped
NPCMLI:	-	Neutral-Point Clamped Multilevel Inverter
DC	-	Diode-Clamped
DCMLI	-	Diode-Clamped Multilevel Inverters
FC	-	Flying-Capacitor
FCMLI	-	Flying-Capacitor Multilevel Inverter
CC	-	Capacitor Clamped
CCMLI	-	Capacitor Clamped Multilevel Inverter
CHB	-	Cascaded H-Bridge
CHBMLI	-	Cascaded H-Bridge Multilevel inverter
PWM	-	Pulse Width Modulation
PD PWM	-	Phase Distortion Pulse Width Modulation
POD PWM		Process Opposition Disposition Pulse Width Modulation
APOD PWM		Alternate Process Opposition Disposition Pulse Width Modulation
THD	-	Total Harmonic Distortion
MOSFET	-	Metal Oxide Semiconductor Field Effect Transistor
FFT	-	Fast Fourier Transform
ONLM	-	Optimum Nearest Level Modulation
Hz	-	Hertz

LIST OF SYMBOLS

V	-	Volt
Vdc	-	DC side input voltage
S	-	Switch
C	-	Capacitor
D	-	Diode
m	-	Number of levels
m_{level}	-	Number of levels
ma	-	Amplitude modulation
Am	-	Amplitude of the reference signal
Ac	-	Amplitude of the carrier signal
fc	-	Frequency of the carrier signal
f_m	-	Frequency of the reference signal
N_{step}	-	Number of levels
N_{switch}	-	Number of switches
N_{diode}	-	Number of diodes
n	-	Number of capacitors
R	-	Resistor
L	-	Inductor
mH	-	Millihenry
F	-	Farad
Ω	-	Ohms
$V_{out,max}$	-	Maximum output voltage

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Renewable energy is an important option available to all due to the ever-increasing current and future demand for electric energy. The attempt to rely on this clean energy will reduce dependence on other traditional energy sources, some of which cause environmental pollution. Renewable energy sources play an essential part in the whole world. It is impossible to connect electricity from renewable energy sources into the primary grid or to our homes directly without converting from DC to AC.[1]

In particular, solar energy and wind energy are the two sources that are receiving increasing interest from people and advancements in power electronic techniques in energy electronics.[1] The energy generated from renewable sources is to feed the household loads, but the surplus energy can be transferred to the public grid.

In short, by using the low switching frequency technique to minimize the quantity of switching and rise reliability. The multilevel inverter is acceptable for two modulated fundamental switching by pulse width modulation techniques and the nearest level control technique.

This project aims to research the multilevel inverter based on the switched-capacitor to produce a five output level using MATLAB Software to improve the design from fewer components.

1.2 Inverter

A DC-AC converter whose output is the desired output voltage and frequency is considered an inverter, which can be generally divided into inverters depending on their operation; Voltage Source Inverters (VSI) and Current Source Inverters (CSI). A voltage of source inverter in which a voltage waveform is the independently operated AC output. One of which the independently regulated ac output is a new waveform is a current source inverter. Based on semiconductor unit contacts, the inverters are listed as; Bridge inverters, Series inverters, and Parallel inverters. Any commercial inverter uses are for adjustable-speed ac drives, induction heating, aircraft power supplies, machine UPS.[2]

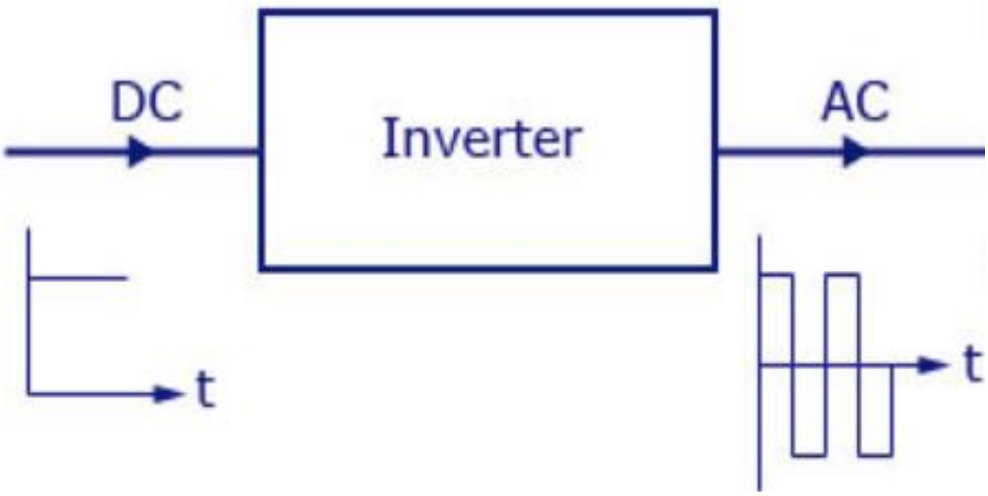

Figure 1 Inverter

1.3 Multilevel Inverter

These multilevel inverters have an excellent ability to work at high voltage levels using low voltage control devices. As the number of levels increases, the topology of these multilevel inverters reduces the total harmonic distortion (THD) intensity of the output voltage. However, the number of power devices is also growing, which increases the inverter's complexity and cost.[3]

A multilevel inverter (MLI) is an electrical device that converts a dc power supply into an ac power supply. In recent years, due to multilevel Inverter (MLI) availability and high performance, MLI topologies have become quite common in high-power converter technology.

Multilevel inverters have many advantages: low switch voltage stresses, low electromagnetic interference, low harmonic distortion, more redundant condition, high efficiency, and low cost. These benefits inspire scientists to give greater attention to improving the high efficiency of multilevel inverters for different applications. This study will use the multilevel inverter (MLI) technique. The multilevel inverter has three types can see below and in Figure (2):-

1) Diode-clamped multilevel inverter.
2) Flying-capacitor multilevel inverter.
3) Cascaded H-Bridge multilevel inverters.

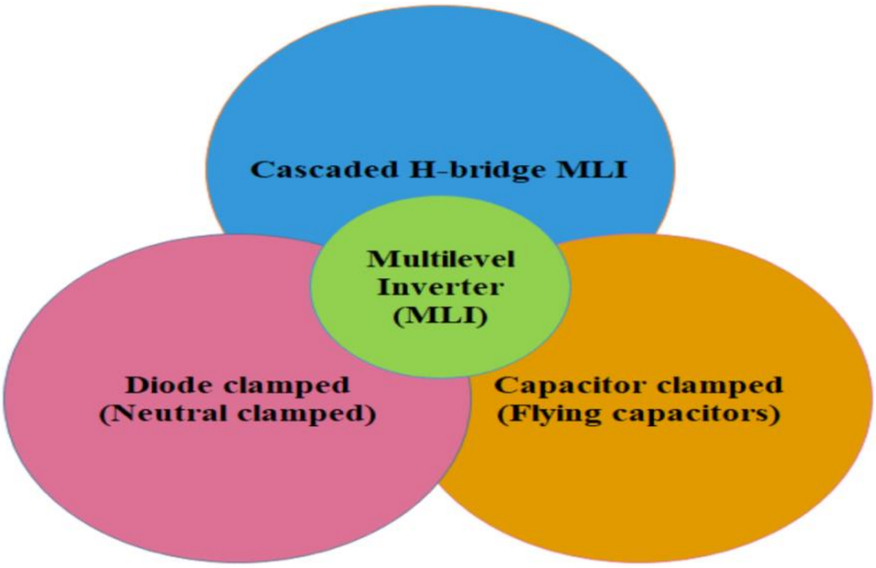

Figure 2 shows the three types of multilevel inverter with different names.

1.4 Switched-Capacitor

A switched-capacitor (SC) is typically created along with a switch and a capacitor.[4] For several years, switched-capacitor (SC) has been used in DC-DC converters; SC converters are not big and operate at high switching frequencies. This technique opened many ways for high power density converters to be designed and attracted the interest of research staff and manufacturers.

Figure (3.a) shows a switched-capacitor (SC). It comprises (C1) and (C2), S is the main switch, S1 and S2 are two slave switches, and three diodes. The switch S, the main and the slave switches, is mutually operated; after, the slave switches are off while the main switch is on, and vice versa.

The slave switches are off while the main switch S is on, and all diodes conduct. The circuit equivalent is seen in Figure (3.b). Both SCs are charged in the steady-state by the source voltage. The slave switches are on while S, the main, is off, and all the diodes are blocked. The circuit equivalent is seen in Figure (3.c). The voltages in the steady-state at points 1, 2, and 3 are E, 2E, and 3E, respectively.

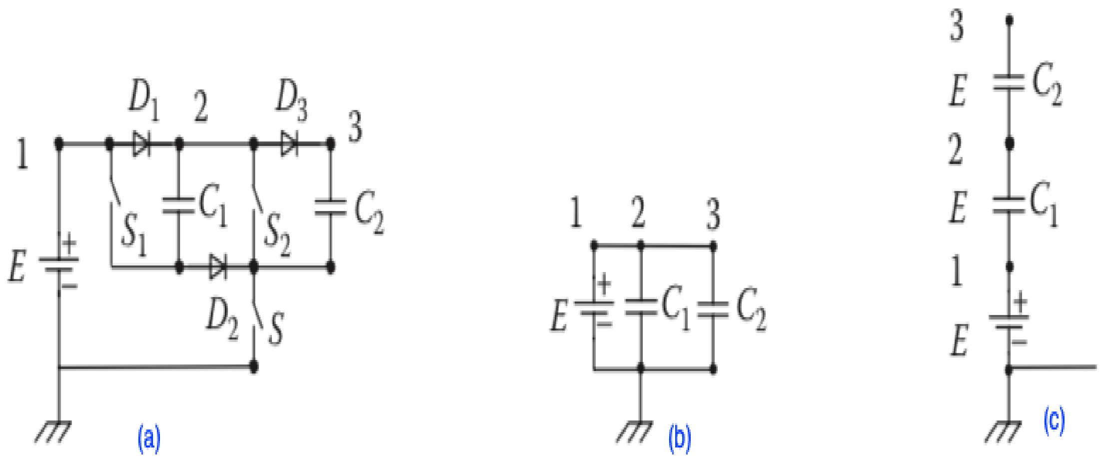

Figure 3 (a) The circuit. (b) The equivalent circuit for switch S is on. (c) Switch S is off.

1.5 Problem Statement

The primary issue with multilevel inverters is that they use many electronic control devices (components) that make the design more Complicated and increase costs in their structure.[5] The idea of using an MLI with direct current sources is widely used in most countries of the world to generate renewable energy, especially in developing solar power (PV), for many reasons.

MLIs have many advantages compare to traditional inverters. However, they suffer from that it needs many components to obtain the most significant number of output levels so that the output wave is close to the sinewave. That will reduce the THD ratio, which also makes the electrical circuit very complex. Because of it, the cost increases much. Also, increasing the number of power devices reduces performance and efficiency. Switched-capacitor-based Multilevel inverter topology is a popular topology that has many advantages. The number of devices used in the circuit is very suitable and is organized economically.

For example, in Flying Capacitor Multilevel Inverter (FCMLI), if the required number of the output level is (m= 5), the number of power switches can be calculated as [N = 2 (m-1) = 8] by using the general equation [N=2(m-1)].

N= number of power switches.
m= number of levels.

This case is not only for FCMLI but for all types of multilevel Inverters. The result will have five output voltage levels with only eight switch devices. Also in this design will have five-level output levels but with only six switches, not eight means that are reducing two switches from conventional multilevel inverter circuits. Thus, the total harmonic distortion (THD) decreases, and with fewer components simultaneously, the inverter performance will improve.

The design has one DC source that only reverses the traditional type, such as Cascade H-bridge MLI. This design will boost up the input voltage to get a dual output voltage.

1.6 Project Objectives

This project aims to design a strategy for multilevel inverters using switched-capacitor units that reduce the number of power electronic components. The objectives of this research are as showing below;

1) Develop a topology for multilevel inverter by using a low number of switches and increasing the number of levels simultaneously.

2) Increasing the input voltage by using the proposed topology, which gives double output voltage.

3) To validate the performance of the new topology offered, the simulation to be carried out using the MATLAB software.

1.7 Project Scopes

The scope of this project study and design the topology of multilevel inverter for Switched-Capacitor based Multilevel Inverter (SCMLI). It can be described the scope as below;

1) Design a five-level output voltage circuit of a Switched-Capacitor based Multilevel Inverter topology requiring fewer components than the traditional topologies

2) The modulation strategy that will be used is the pulse width modulation PWM technique.

3) The model will be simulated using MATLAB/SIMULINK software.

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