A STUDY OF A CASCADED H-BRIDGE MULTILEVEL INVERTER (CHB-MLI) PERFORMANCE BASED ON PARTICLE SWARM OPTIMISATION (PSO) AS A CONTROLLER

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DECLARATION

I declare that this thesis entitled "**A STUDY OF A CASCADED H-BRIDGE MULTILEVEL INVERTER PERFORMANCE BASED ON PARTICLE SWARM OPTIMIZATION AS A CONTROLLER**" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this report entitled "A study of Cascaded H-Bridge Multilevel Inverter Performance Based On Particle Swarm Optimisation as a Controller" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

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Supervisor Name : .....

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DEDICATIONS

To my beloved father, mother, brothers and sisters.

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In the name of Allah, the Most Beneficent and The Most Merciful. It is a deepest sense gratitude of the Almighty that give me strength and ability to complete the Final Year Project report.

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ABSTRACT

The smoothness of the waveform of the multilevel inverter output, especially for the voltage waveform is crucial as can protect the electrical equipment from damage. In order to maintain the sinusoidal waveform of the voltage waveform of the multilevel inverter is totally dependent to the controller. This project aims to design and model of a single phase of a cascaded H-Bridge Multilevel Inverter (CHBMLIs) for five levels using Particle Swarm Optimization (PSO) for the better output of the waveforms for the voltages and currents. The performance of the proposed CHBMLIs for five levels will be monitored, evaluated and analyzed through simulation and experimental results in term of their THD values.

KEYWORDS : CHBMLIs, PSO, THD

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ABSTRAK

Kelancaran gelombang bentuk output inverter bertingkat, terutamanya untuk bentuk gelombang voltan adalah penting kerana dapat melindungi peralatan elektrik dari kerosakan. Untuk mengekalkan gelombang sinusoidal bentuk gelombang voltan penyongsang bertingkat itu bergantung sepenuhnya kepada pengawal. Projek ini bertujuan untuk merekabentuk dan memodelkan satu fasa H-Bridge Multilevel Inverter (CHBMLIs) yang diselaraskan untuk lima tahap menggunakan Pengoptimuman Swarm Partikel (PSO) untuk keluaran gelombang yang lebih baik untuk voltan dan arus. Prestasi CHBMLI yang dicadangkan untuk lima peringkat akan dipantau, dinilai dan dianalisis melalui hasil simulasi dan eksperimen dari segi nilai THD mereka.

KATA KUNCI : CHBMLIs, PSO , THD

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Inverter is one the type of converter that change direct current (DC) power into alternating current (AC) power to get the desired frequency and output voltage. It is also known as two-level inverter. The multilevel converter has drawn many interest in power industry due to its structure that easier to produce an output of high voltage from medium voltage source. The main constraint of multilevel inverter lies to the usage of the switches to avoid the switching losses. Multilevel inverter allows the system to reach a high voltage output with low harmonic without the use of a transformer or a series-connected synchronised switching device. As the number of voltage level increase, the harmonic content of output voltage's waveform decrease significantly.

There are many topologies that has been proposed such as diode-clamped, flying capacitor and cascaded multilevel inverter [1]. Cascaded H- bridge has always been famous due to its feature that optimise the circuit layout and packaging as each level has the same structure. The advantage of cascaded H-bridge over other topologies is that its require less number of component to achieve the same voltage level. As each level has the same structure and there are no extra filtering circuit, it is possible to have an optimised circuit layout and packaging. The only drawback of this inverter is that its use a large number of semiconductor switches and its need separate dc sources for real power conversion.

The research in the area of power electronics especially in multilevel inverter is still relevant to explore as there are few areas in the multilevel inverter that can still be improved. Particle Swarm Optimisation (PSO) algorithm is proposed in this project to reduce the effect of non-triple harmonic from the output of multilevel inverter. This topology of inverter is important because multilevel inverter is better than conventional inverter which contain only 2 DC level as multilevel inverter produces lower switching losses, electromagnetic interference and harmonic distortion. As there are parameters that still can be improve in multilevel inverter, this project is still relevant to study. Multilevel inverters are promising as they have nearly sinusoidal output-voltage waveforms, output current with better

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harmonic profile, less stressing of electronic components owing to decreased voltages, switching losses that are lower than those of conventional two-level inverters, a smaller filter size, and lower EMI, all of which make them cheaper, lighter, and more compact [3], [4]. The controllers which are applied to the multilevel inverter play an important role in order to produce a smooth waveform of the multilevel inverter. There are so many types of the controllers which are applied to the multilevel inverter such as Pulse Width Modulation (PWM) technique, fuzzy, space vector PWM (SPWM) and Newton Raphson (NR) technique. All these types of the controller have the merit and demerit respectively. In this project, the Particle Swarm Optimization (PSO) algorithm will be used and it will be applied to the design of the Cascaded H-Bridge Multilevel Inverter (CHB-MLI) for five levels. Figure 2.1 shows the model of the Cascaded H-Bridge multilevel (CHB-MLI). Particle Swarm Optimisation is the most optimise algorithm to define the optimal solution of the non-linear problems and enhance the power quality when applied to a high voltage application system. Particle Swarm Optimisation (PSO) technique will compute the optimum switching angle which affect to get a lower percentage of harmonic distortion in term of THD.

1.2 Problem Statement

Nowadays, high power application system demands a better power quality supply to gain a better output. However, harmonic distortion in term of Total Harmonic Distortion (THD) is always the problem due to high switching losses which affected by switching angle in the inverter. It is important for the waveform of the inverter output to be maintained sinusoidal and free from the distortion. Cascaded H-Bridge Multilevel Inverter (CHBMLIs) will be proposed because it produce a lower percentage of THD as the harmonic distortion reduced.

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1.3 Objective

- To study the concept of multilevel inverters and their controllers which are used for harmonics reduction of the output waveform of the multilevel inverters.

- To model and design a modified cascaded H-bridge multilevel inverter (CHB-MLI) based on particle swarm optimization algorithm by using MATLAB/SIMULINK software for the aims of the simulation.

- To implement and test the hardware prototype of a modified single phase five levels cascaded H-Bridge multilevel inverter and verify with the simulation results.

1.4 Scope of work

The scope of this project includes understanding and analysing the performance of the topology of the multilevel inverter that used in the project which is the cascaded multilevel inverter. The performance of the multilevel inverter is analyse by differentiate a few parameters which comprise of total harmonic distortion(THD) and switching losses. Particle Swarm Optimisation is used as a method to control the multilevel inverter to get the desired output. The simulation and the coding control are done by using MATLAB software and the implementation of the hardware is tested.

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CHAPTER 2

LITERATURE REVIEW

2.1 Theory and basic principle

2.1.1 Cascaded H-Bridge Multilevel Inverter

Over the past decades, there are various type of topologies have been introduced for multilevel inverter as a respond to the increasing demand of high power applications in the industry. Multilevel inverter is more suitable to be use in the industrial area than two level inverter because of the advantages that being offered by the multilevel inverter's features. Multilevel inverter gives a higher efficiency, lower switching stress and electromagnetic interference which resulting in a better power quality. Multilevel inverter can be separated into three major topologies which is flying capacitors, diode-clamped and cascaded H-bridge. Among of these topologies, cascaded h-bridge multilevel inverter is the most convenient to be implement because of the simple modular and structure [2]. In 1970s, Baker and Bannister founded the first copyright for the converter topology which can produce multilevel voltages with various source of DC supply. In this topology, the cascaded multilevel inverter has several structure of single phase full bridge inverter that connected together. The voltage input is connected with the H-bridge which will produce output voltage. In cascaded multilevel inverter, the number of voltage level of output phase depends on the number of voltage supply which formulated through n = 2s+1 [3]. As the level of inverter increases, the stepped waveform become almost sinusoidal and reduce the harmonic distortions. The Figure 2.1 shows a single phase cascaded multilevel inverter model. The voltage output vary from $+V_{dc}$, 0 and $-V_{dc}$.

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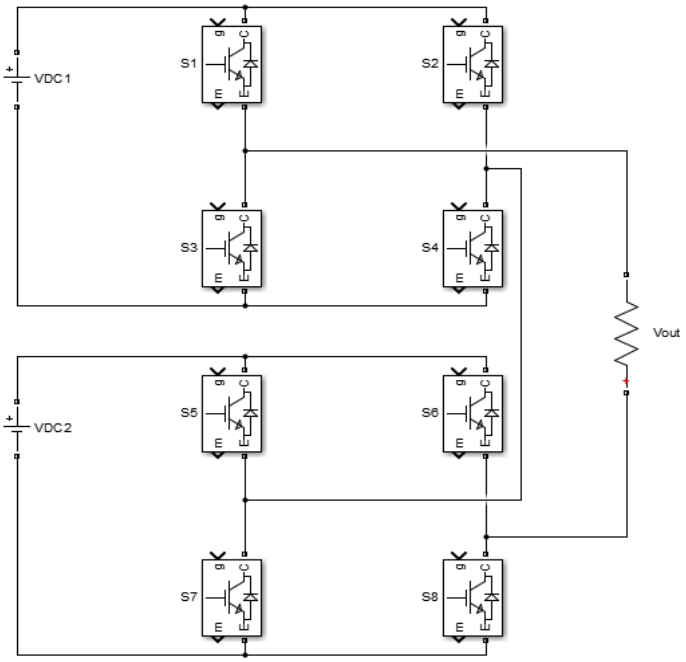

Figure 2.1: 5-level CHB-MLIs

2.1.2 Total Harmonic Distortion (THD)

Harmonic distortion in power system application is not a new case anymore. Every power system application has issues in their output regarding harmonics. Harmonic distortion will affect the power outcome as it produces a bad power quality [4]. The sudden demand of power electronic loads in a power system application starts in the early 1990. It has a good controllability and efficiency but the drawback is that the present of non-sinusoidal currents. Previous study shown that harmonic distortions in power system application will increase parallel with power electronic device continue to evolve [5]. Total Harmonic Distortion (THD) is the common term used to measure the harmonic distortions. Total Harmonic Distortion(THD) is apply to both the current and voltage and is varies from 0% to 100%. Normally the THD of the voltage is less than 5% whereas value above 10% is unacceptable and will damage the sensitive equipment and loads [6]. THD is defined as:

$$THD = \frac{100\sqrt{\sum_{h=2}^{k} U_{hrms}^2}}{U_{1rms}} \quad (2.1)$$

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2.2 Comparison of previous work

There are few journals and articles about previous work related to this project that had been reviewed to help understand more about the performance parameter of the cascaded H-bridge multilevel inverter. In this review, the study about the configuration of the modulation technique to minimise the harmonic distortion will be discussed.

2.2.1 Selective Harmonic Elimination PWM Method

The title of report should be as concise as possible, giving an accurate description of the In this study, there are many methods to minimise the harmonic but only SHE-PWM that select proper switching angles to eliminate low-order harmonics and minimise the THD of the output voltage from the system. In this method, the problem can be solved by three ways which is Newton-Raphson method, Genetic Algorithm (GA) and Particle Swarm Optimisation (PSO). Genetic Algorithm and Particle Swarm Optimisation are used to calculate the non-linear transcendental equation which will determine the best possible switching angle in cascaded H-bridge multilevel inverter. Selective Harmonic Elimination PWM used Fourier expansion to calculate critically the odd harmonic in the output phase voltage. The Fourier analysis is formulated as below [8]:

$$V(wt) = \sum_{n=1}^{\infty} V_n \cos(nwt) + V_n \sin(nwt) \qquad (2.2)$$

V_n is the amplitude and the voltage waveform of n_{th} harmonic component. Selective Harmonic Elimination PWM will mitigate the low order harmonic whereas the other harmonic is eliminated by using filter. For example, this method can eliminate the odd harmonic such as 3rd, 5th and 7th harmonics and has been translated into transcendental non-linear equation as below [7]:

$$V_n = \frac{4}{n\pi} V_{dc}(na_1) + V_{dc}(na_2) + V_{dc}(na_3) \qquad (2.3)$$

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2.2.2 Genetic Algorithm

In the previous study, genetic algorithm is proposed where the switching angle is calculated in context of step modulation. This topology has the same purposed with other method which is to minimise the THD. Genetic algorithm reduces the computational calculation as well as the search time as it is inspired from the law of natural selection [9]. This method has been theoretically established to deliver solution in complex search spaces. Below shown the flow chart of the steps to minimise the total harmonic distortion (THD).

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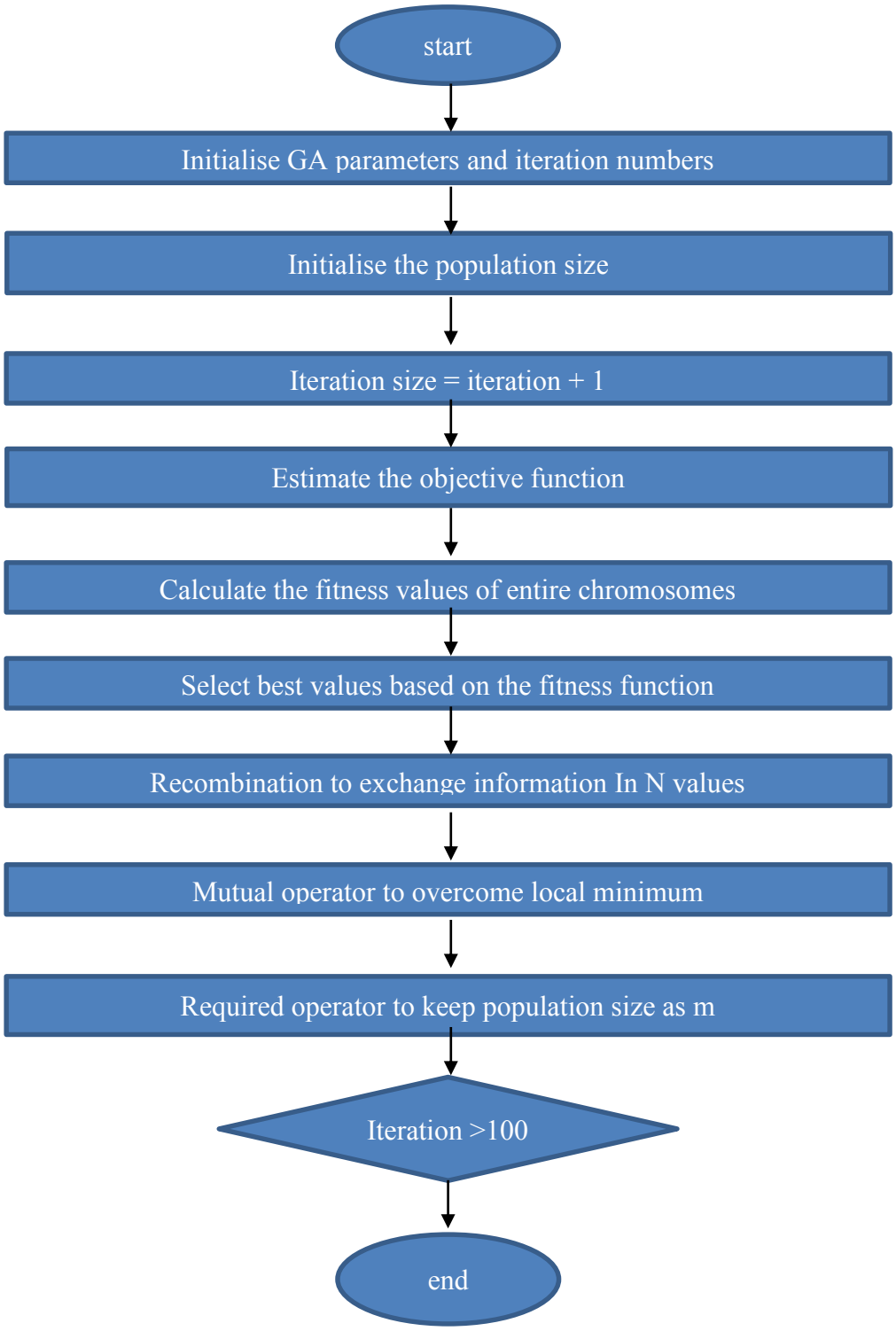

Figure 2.2: Flowchart of Genetic Algorithm

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2.2.3 PSO

Particle swarm optimisation is more easy in concept and implementation compared to other algorithms and technique. It is consisting of velocity vector and position vector. This method is implemented to several level of the multilevel inverter to compute the best switching angles [2]. Other harmonic elimination methods have a number of limitation and also provided poor result. A simulation had been analyse and the result indicate that Particle Swarm Optimisation method produce a better outcome than other method as it produced a lower THD. Table 2.1 show the result of comparison of a few methods[10]

Table 2.1: Comparison of algorithm's result

Proposed method	Levels	Harmonics	THD (%)	Limitations
Artificial Neural Network	7-level 11-level	5,7,11,13	7-level = 14.57% 11-level = 9.79%	ANN produce higher THD than GA
Bee Colony Optimisation	7-level	5,7	9.57%	BCO produce higher THD than GA
Comparison of Newton Raphson and Genetic Algorithm	7-level	3,5,7	NR = 11.68% GA = 6.61%	GA consume high time
Simulated Annealing Algorithm	9-level	5,7	8.99% (consume less time than GA)	SA algorithm produce high THD% compare to GA

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