UNIVERSITI PUTRA MALAYSIA

PWM INVERTER FOR ELECTRIC DRIVE TRAIN APPLICATION

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By

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LIST OF ABBREVIATIONS

PWM	Pulse Width Modulation
MPWM	Multiple Pulse Width Modulation
MGD	MOSFET Gate Drive
EV	Electric Vehicle
HVIC	High Voltage Intergrated Circuit
HVAC	High Voltage Alternating Current
UPS	Uninterruptable Power Supply
TTL	Transistor-Transistor Logic
CMOS	Complementary Metal Oxide Semiconductor
ITRIP	Current Trip
IGBT	Insulated-Gate Bipolar Transistor
BJT	Bipolar Junction Transistor
PLD	Programmable Logic Devices
UV	Ultra Violet
AC	Alternating Current
DC	Direct Current
PCB	Printed Circuit Board
PMCM	Permanent Magnet Commutator Motor

PMBM	Permanent Magnet Brushless Motor
SM	Synchronous Motor (brushless DC motor)
IM	Induction Motor (squirrel cage)
SRM	Switched Reluctance Motor

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PWM INVERTER FOR ELECTRIC DRIVE TRAIN APPLICATION

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Controlling AC power load using DC supply requires complex design and circuit. Basically the controlling system comprises of low power control unit, inverter and the load. Multiple Pulse Width Modulation (MPWM) technique was used for controlling the control unit design as it gives low harmonic distortion compared with other types. Six MPWM signals were used to trigger the six channels in inverter circuit and all the signals were synchronous to avoid short circuit in inverter circuit. The design of the MPWM was simplified with an IC IR2130, which provided matched voltage trigger, adequate dead time for low and high channels and over current shut down. In inverter circuit design the main component in controlling the high current flow from DC supply to load is power device. There are various power devices available in

the market but IGBT was chosen due to its high current rating and simple triggering process. Apart from single IGBT with high current rating being used in each channel; paralleling several IGBTs is also the technique that can be used to increase the power conversion in inverter circuits and to reduce the cost of design. It is evident that by paralleling several low current power devices, the amount of current produced equates the single high current power device. For the AC load, three-phase squirrel cage AC motor was chosen after comparing with other types of motors as it provides several advantages in terms of being robust, cheap and maintenance free.

Overall result showed there was smooth control of AC motor using single configuration technique compared to using parallel configuration technique. Further investigations are required especially on the use of parallel configuration technique with IGBT as power device and also in simplifying the complex snubber circuit, needed for protecting power devices in inverter circuit from high current and voltage transients.

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PENYONGSANG PWM UNTUK KEGUNAAN PEMICUAN ELEKTRIK

Oleh

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Pengawalan beban kuasa arus ulang alik dengan menggunakan sumber arus terus melibatkan rekabentuk dan litar yang kompleks. Secara umumnya sistem pengawalan tersebut terdiri daripada unit kawalan, penyonsang dan beban. Teknik multipel lebar denyut pemodulat (MPWM) digunakan untuk unit kawalan memandangkan ia mampu mengurangkan gangguan ayunan rendah berbanding dengan teknik yang lain. Enam denyutan MPWM digunakan untuk memicu enam saluran penyongsang dan enam denyutan tersebut disinkronasikan untuk mengelakkan litar pintas di dalam litar penyongsang. Litar unit kawalan di permudahkan dengan menggunakan peranti IR2130.

Peranti ini menghasilkan voltan picu yang selaras dengan peranti suis, masa keselamatan untuk saluran atas dan bawah di dalam litar penyongsang dan suis auto untuk arus lebihan. Litar penyongsang direkabentuk dengan menggunakan peranti kuasa tinggi. Terdapat berbagai-bagai jenis peranti kuasa tinggi terdapat dipasaran tetapi peranti IGBT dipilih kerana ia dapat menawarkan arus tinggi dan picuan yang mudah. Selain peranti kuasa tinggi, penyambugan selari juga mampu menambahkan kuasa litar penyongsang dan mengurangkan kos rekabentuk. Penyambungan selari beberapa peranti kuasa rendah boleh menghasilkan kuasa yang sama dengan peranti yang berkuasa tinggi. Untuk beban arus ulang alik, motor squirrel-cage digunakan setelah didapati ia memberi berapa kelebihan dari segi tahan lasak, murah dan tiada kos penyelanggaran.

Keseluruhan rekabentuk menunjukkan bahawa kawalan motor AC dengan menggunakan rekabentuk biasa (satu peranti) adalah baik dan lancar tetapi kurang berkesan untuk rekabentuk sambungan selari. Penyelidikan seterusnya di perlukan untuk litar penyongsang menggunakan sambungan selari khusus menggunakan peranti IGBT dan juga litar snubber yang digunakan sebagai litar keselamatan untuk mengawal arus dan voltan lonjakan.

CHAPTER I

INTRODUCTION

Background

Electric vehicle drive train is a system, which uses battery as the source of energy, converter to reform the energy and motor to drive the machine. Recently it becomes in demand since the solution of getting high power semiconductor is being solved and long life duration of batteries being invented. Basically in electric drive train system the converter plays the most important role. With the present technology of power semiconductor it has been tremendously developed to suit the various requirement of the loads. High power loads consumes high power from the source. Therefore the intermediate converter must be capable to support the conversion process efficiently and effectively.

The power rating of the converter must correlate with the power of the load. In determining the power rating of power switches the equivalent power rating between converter and load must be achieved. In other words the power rating of the load must match the power rating of the converter. Among the components in the inverter circuit power switches are the most expensive item. The suitable power rating of the power switches must be properly calculated in order to meet the requirement of the power rating of the converter. An easy solution is to get the power switches with power rating slightly higher compare to the calculated value. However this procedure might not be applicable for certain applications particularly to the cost that need to be paid. It is understood that the higher the rating of power switches the higher the cost of the power switches. With this kind of constrain an option is required to be implemented to meet the same objective. One of the reasonable techniques recommended is by paralleling few power switches, which will increase the current rating to multiple number of the power switches used. However the parallel technique must be properly studied to avoid damages to the power switches.

The selection of power switches is also important. Many types are available in the market nowadays. The most common are BJTs, MOSFETs, SCRs, IGBTs, MCTs, SITs and etc. The availability, power rating and simple in triggering are the criteria that are required by most designers. Among the power switches IGBT seems the right choice to be used. It has combination characteristics of MOSFET and BJT. Its advantage compared to MOSFET is its availability of power rating, which is up to 1000 A.

A converters which converts dc source to ac source is called inverter. AC loads need AC source to run. For electric vehicle application the source of energy comes from DC batteries, which is required to be converted to AC source to move AC motor. AC motor is chosen with regard to their robust, free maintenance, and low cost. Three phase AC motor is suitable for high power application. To support the power need by the three-phase motor, a three-phase inverter must be used. In normal implementation minimum six power switches are used for an inverter circuit. However the cost of developing is high if the rated power switches are based on the calculated power needed. Therefore to meet the same power rating each power switch will be replaced with three IGBTs which has lower power rating. The total number of IGBTs in the design becomes 18 units but the total cost is significantly reduced.

The control unit functions to trigger the power switches in the converter circuits. The triggering time must be properly set to get the outputs waveform as required. There are several circuits that can be used such as analogue comparator, digital sequential circuit and microcontrollers. The whole unit of control unit is complex. Basically it comprises three sections which are low power control unit, isolation circuit and MOS-Gated Driver. However with the advance technology, the size of the circuit is reduced into several ICs only. This definitely also reduced the size of the PCB driver circuit. On top of that the IC also has additional features such as high overload current protection.

There are two techniques of controlling the inverter circuit; voltage control or PWM control. Voltage control is a method achieved varying the DC source using chopper. It has several drawbacks such as high harmonics content and low power factor. PWM or pulse width modulation has better performance against voltage control technique. Besides eliminating the drawbacks of voltage control technique, the circuit is also simple and less cumbersome. There are several PWM techniques that can be implemented such as MPWM, SPWM, and etc. The number of pulses and the size of pulse in each duty cycle are the criteria that is being investigated in PWM technique to eliminate the harmonic contents.

Objectives

The objectives of the study are divided into three major topics, which are as follow;

1. Developing pulse width modulation (PWM) driver unit. To meet the specification of the PWM control technique, four sub aims are required ;

- To design a PWM signal which consist of six pulses per cycle.
- To design six PWM signals to trigger six channel of inverter circuit with each signal is delayed with 60° to next pulse signal.
- To design a controller which is used to synchronise the outputs signals simultaneously.
- To minimise the complexity of the circuit using programmable logic devices (PLD).

2. Developing power driver unit. To meet the specifications of the circuit, four sub aims are required which are as follow :

- To design six PWM signal with Vpp equal to 15 V.
- To design three high side floating gate drives and associated level shifting circuits from ground to floating references.
- To design three low side gate drives and associated level shifting circuits from logic ground to power ground references.
- To design current sensing amplifier monitoring overload condition.
- To design current buffer circuit to increase current pulse signal. The signal must have significant amount of current to trigger single IGBT or parallel IGBT.

3. Developing an inverter circuit. Three sub aims are required to meet the specification of the design.

- To develop three-phase inverter with two type of configuration, normal and parallel.
- To specify the output of inverter with 100 Vac.
- To compare the performance of inverter using normal configuration and parallel configuration of power switches in controlling speed of AC motor.

CHAPTER II

LITERATURE REVIEW

Electric Drive Train System

Electric power train is the main part in electric vehicle system. It comprises three major areas - controller unit, power electronics and motor. The controller unit depends mainly on the control technique and hardware approached. It provides control signals to the high power converter. The signal is amplified via a drive to turn on/off proper power devices of the converter. The function of the converter is to transfer and regulate with high efficiency the power from the main supply to the motor. Method in controlling the converter depends on the type of load either DC load or AC load. Finally the type of battery and its energy and power capabilities must also be considered in designing the complete electric power train.

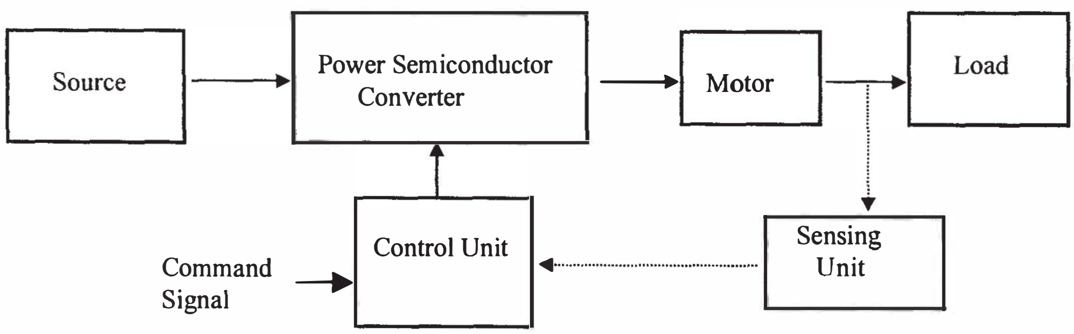

Figure 1: Block Diagram of an Electric Drive Train[Gopal, 1989].

Drive Control Unit

The drive control unit controls the converter operation in a proper manner and at the same time maintains the safety of the converter. It operates at much lower voltage and power levels. The control unit consists of linear and digital integrated circuits and transistors. Microcomputers, microprocessors, microcontrollers and digital signal processor have made a tremendous impact in implementing the control unit. They enable implementation of sophisticated and complex algorithms for control and protection [Gopal, 1989].

In DC-AC inverter system the drive control unit has been upgraded continuously from complex and large circuit to be integrated in a small IC. Older generation gate drive circuits for inverter typically used optocouplers with a number of discrete devices that tend to results in high component count and large amount of board space. Using the 1200V HVIC technology creates a new architecture for the gate drive circuits of three-phase inverter. It provides in a single chip all the circuits necessary to interface between the microcontroller and the three-phase inverter. One of the leading companies, International Rectifier has developed several products of the driver such as IR2130, IR2131 and etc. The complete versions and their specific applications are summarized in Table 1 [IR AN-985, 1996].

Table 1: IR Drive Models [IR AN-985, 1996].

Product Family	**Maximum Voltage**	**Topology**	**Targeted Applications**
IR2233	1200V	3-phase	Industrial Motor Drives for 460 VAC to 5 HP with integrated protection and compact design.
IR2130, IR2131 IR2132, IR2133	600V	3-phase	Industrial Motor Drives for 230 VAC to 5 HP with integrated protection and compact design
IR2110, IR2113	600V	½ Bridge	High performance and high power inverters using large size IGBT or FET switch.
IR2101, IR2102 IR2103, IR2104 IR2111, IR2112	600V	½ Bridge	Cost sensitive inverter designs for appliance and HVAC
IR2125, IR2127 IR2128	600V	High Side	Inverter designs requiring over-current protection for each IGBT or FET switch and high side error reporting.

Major functional blocks in the IR drive versions for 3-phase inverters include:

- Three high side floating gate drives and associated level shifting circuits from ground to floating references.
- Three low side gates drive and associated level shifting circuits from logic ground to power ground reference.
- Current sensing amplifier.
- Overcurrent trip comparator.

The driver or well known as MOS-gated Driver (MGD) commonly used in motor drives, UPS and converters operating at DC bus voltages up to 600V requires voltage drive in order to achieve a saturated "ON" state condition. The drive signal must have the following characteristics:

- An amplitude of 10V to 15V.
- A low source resistance for rapid charge and discharge of the gate capacitance
- A floating output so that high side switches can be driven.

In addition to the above requirements the actual driver should be capable of driving combinations of devices in both low-side and high-side switch configurations.