"I hereby declare that I have read through this report entitle "Design and development of small-scale regenerating energy using brush DC motor" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic & Drives)"

Signature : ……

Supervisor's Name : …….

Date : …….

DESIGN AND DEVELOPMENT OF SMALL-SCALE REGENERATING ENERGY USING BRUSH DC MOTOR

SUTHAKARAN S/O SOLAMUTHU

A report submitted in partial fulfilment of the requirement for the degree of Bachelor of Electrical Engineering (Power Electronic & Drives)

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2013

I declare that this report entitle “Design and development of small-scale regenerating energy using brush DC motor” is the result of my own research except as cited in references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……

Name : …….

Date : …….

DEDICATION

First of all, I would like to thanks God because able to complete this project and fulfil the requirement for Bachelor of Electrical Engineering (Power Electronic & Drives) successfully.

I was in contact with many people in the midst of preparing this report especially my beloved mother and sister. They have contributed toward my thought and advices. I'm grateful to my mother who had supported and cheered me all the way during my completion of this final project and also during my studies in University Teknikal Malaysia Melaka (UTeM). And not to forget about my sister who had contributed toward my knowledge and support me by financially. And more over she had given advices and ideas to complete this report successfully.

Finally I would like to extend my appreciation and thanks for those who had directly or indirectly helped me undergo this project. I hope this report would be a reference for my future besides being requirement to complete my degree in Bachelor of Electrical Engineering.

ACKNOWLEDGEMENT

In preparing this report, I was in contact with many people, researchers, academicians and practitioners. They have contributed towards my understanding and thought. In particular, I wish to express my sincere appreciation to my main project supervisor, Mr Mohd Saifuzam Bin Jamri. Under his supervision, many aspects regarding this project have been explored and with this knowledge, idea and support received from him, this report can be presented in time given.

I am also very thankful to Master students that have helped me in term of technical support. Through their guide in term of technical I have succeed finishing by circuit and error that I have faced. I also extend my appreciation and thanks for lectures those who had directly or indirectly helped me undergo this project.

My fellow postgraduate students should also be recognised for their support. My sincere appreciation also extends to all my colleagues and other who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space.

ABSTRACT

Regenerative braking is one of the important features for electric vehicle. It serves to convert part of mechanical energy as known as kinetic energy into electric energy during braking. This energy can be stored in device such as rechargeable battery or any storing devices such as super-capacitor for EV improvement. So regenerative braking plays an important role in reducing the energy consumption of EV. It also will increase the driving range and improve its performance. Research forces on electrical vehicles due to the energy crisis. The regenerative braking energy was used to improve the efficiency of an electric vehicle as it recovers energy that could go to waste. A new method of regenerative braking system was tested for a small scale electrical remote control car. The proposed system use an ultra-capacitor bank to absorb and store energy which could be used to regenerate back to the motor to reduce the battery usage due to higher voltage and the higher starting current required by the Brush DC motor for starting. When motor accelerates in regenerative mode, the switching frequency of the current place an important role in controlling the negative torque applied by the motor. The research will show that the proposed regenerative braking system is important in recover energy losses and improve the torque performance than before by 40%. This project involved mechanical, electrical design and construction. Till the end of this project all development and result including analysis, conclusion and recommendation for future have been made in this report.

ABSTRAK

Sistem penjanaan adalah salah satu teknologi yang luar biasa bagi kenderaan elektrik. Ianya berfungsi untuk menukar sebahagian daripada tenaga mekanikal yang dikenali sebagai tenaga kinetik kepada tenaga elektrik semasa membrek. Tenaga ini boleh disimpan di dalam peranti untuk menambah baik kereta electrik. Jadi sistem penjanaan memainkan peranan yang penting dalam mengurangkan penggunaan tenaga pada kereta electrik. Ia juga akan meningkatkan lagi kecekapan memandu dan meningkatkan prestasinya. Satu penyelidikan telah dijalankan akibat krisis tenaga ke atas kenderaan elektrik. Kecekapan kenderaan elektrik dengan enjin pembakaran dalaman yang lebih cekapan berbanding dengan kenderaan yang biasa. Penjanaan semula tenaga digunakan untuk meningkatkan kecekapan kenderaan elektrik kerana ia memulihkan tenaga yang boleh membazir. Salah satu kaedah baru sistem penjanaan untuk skala elektrik kereta kawalan jauh telah digunakan sebagai prototaip dan diuji. Sistem ini menggunakan nultra-kapasitor bank untuk menyimpan tenaga yang dijana dari motor untuk digunakan semula pada motor untuk mengurangkan penghabisan bateri yang cepat semasa menjalankan motor. Apabila motor dalam keadaan mood penjanaan, suis pengawal memain peranan yang penting dalam mengawal torque negatif untuk dipakai pada motor. Kajian laporan ini akan menunjukkan cara dan cadangan sistem penjanaan ini adalah penting dalam memulihkan kehilangan tenaga dan meningkatkan prestasi torque daripada sebelumnya sebanyak 40%. Projek ini melibatkan rekaan dan penbangunana, pemprograman dan penyelesaian masalah yang timbul. Di akhir project ini, semua pembangunan dan keputusan termasuk analisis, kesimpulan dan cadangan untuk masa depan telah disempurnakan di dalam laporan ini.

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CHAPTER 1

INTRODUCTION

1.1 Background and motivation

Regenerative braking is one of the unusual technologies for electric vehicle. It serves to convert part of mechanical energy as known as kinetic energy into electric energy during braking. This energy can be stored in device for EV improvement. So regenerative braking plays an important role in reducing the energy consumption of EV. It also will increase the driving range and improve its performance. There are many research done about regenerative braking and different type of matted have been proposed.

This technology mostly used in car because the traditional braking system always use mechanical friction to split the kinetic energy as heat energy cause of stopping. When operating a vehicle, one third to one half of energy been use by the vehicle during braking. The kinetic energy is an excessive energy when the electric motor is in the braking state since it dissipated the energy and causes a loss of the overall energy. This wasted energy can be converted to useful energy.

This project motivate due to energy crisis in electric vehicle EV that had lot of issues on power consumption. This system is designed to improve the issues on power consumption and overall increase the performance of EV. From this improvement the usage of power to charge can be lest and can save and reduce the power losses.

This project will be explaining about how this wasted energy been used back and overall improves the EV performance and reduce the power losses in battery. The matted

will be used to improve the performance is by using an ultra-capacitor. This ultra-capacitor will be used to store the wasted energy when regenerative braking and utilize the energy back to motor. By this behave, the usage of battery power will be lesser and the torque performance of the motor will be increased.

1.2 Problem Statement

In order to start up a brush DC motor, it requires a higher current for the armature to increase the torque performance. When the torque performance increase the speed will increase too. Each time the motor run in forward condition, a higher amount of current will be produce at the armature of the motor where this current been engaged from the power supply (battery). Each time the battery delivers a higher current, it will lose a bigger among of power. This will make the battery energy drop faster.

In order to solve this problem a system had been design to reduce the usage of power supply and further more increase the performance of the brush DC motor. This system work by storing the generated power by the DC motor when the motor act as generator into a ultra-capacitor. Then, this energy will be used when each time the start forward button been press. This energy will support to reduce the higher usage of starting current and also increase the torque performance when start up the motor that had been explained more detailed in chapter 4 (result and discussion).

Upon the completion of this project it will benefit to many systems that using brush DC motor. This system are purposed to apply the application to electric vehicle. So, this system more useful for EV car.

1.3 Project Objectives

The objective of this project is to develop small-scale regenerating energy using brushed DC motor that will have following abilities and properties:

i) Identify the suitable connection for ultra-capacitor in the circuit.
ii) Development of small-scale regenerating energy using brush DC motor
iii) Reduce the fast battery energy drain when staring the brush DC motor and increase energy efficiency to battery life last long.
iv) Improve the torque and speed performance.

1.4 Scopes/Limitations

As this project purpose was to design and develop a regenerating energy, it will be only cover on:

i) A small scale electric remote control car will be used based on the modular design to repower an electric vehicle to implement this project.
ii) Do analysing and simulation on the torque performance (speed) before and after completing this project by using MATLAB.
iii) Calculate the rated value of ultra-capacitor that going to be used.
iv) Analysis the amount of energy and current produced by the brush DC motor when it acts as generator (regenerating breaking).
v) Review the amount of voltage losses before and after completing this project.
vi) Observe the performance of the car before and after completing this project by derive a graph speed VS time.

Chapter 2

LITERATURE REVIEW

Literature review has been taken place on the beginning of the project as it started. The purposes of this process are to searches and gather the knowledge and information needed to ensure that the project will progress smoothly and successfully. This process was help continuously until the completion of this project since the information and knowledge are always needed throughout the development of this project. There are several important parts need to be researched to ensure the functionality of the system. Every important part in this researched based on theories, journal or thesis from past researchers.

2.1 Implementation and Performance Evaluation of a Regenerative Braking System Coupled to Ultra-capacitors for a Brushless DC Hub Motor Driven Electric Tricycle by Kuruppu, Sandun

Regenerative braking technology on recovering energy studies has been made before this. This technology breaking has been made either in electrical way or mechanical way. Now days, electric vehicle have many ways of regenerative braking to recover energy. However the braking technology still not fully classified as electrical regenerative braking. There are supported by mechanical regenerative braking as well. Electrical vehicles normally used less power and it operate more efficiently compare to gasoline vehicles. It has a built in system that can converted from electrical energy to mechanical energy which it can function as generator when braking, moving downhill or when slowing down. [1]

2.2 Braking power analysis

The research mainly forces on the way how the vehicles produce energy and ability to recover it via regenerating breaking. It's also including the weight of the vehicles and the way of handling capability of the electrical system.

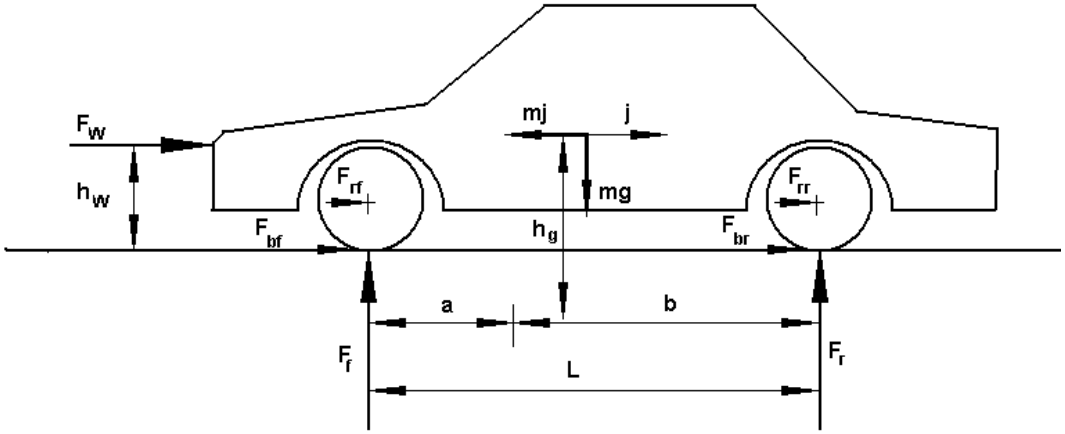

Figure 2.1: Forces acting on a vehicle while braking on level ground

j = the deceleration of the vehicle **Fw** = the aerodynamic resistance
fr = the tire rolling resistance **r** = tire radius,
Fbr & **Fbf** = rolling resistances on the rear and front wheels respectively

Instantaneous Energy = ½*m*V^2 ……[1]

The amount of absorbed power is different depending on the weight of the vehicle and how fast the deceleration. Most of the regenerated energy is from the inertia of the vehicle. The energy capturing devices is what absorbs the electric energy during regenerative braking.

2.3 Energy Capturing Devices

There are a lot of different types of battery able to store energy, include lead acid, Li –ion, Li polymer and Nikel Cadmium. Electrical energy storage is few used in electrical vehicles. Each battery type has its own advantages and disadvantages. The weak point using battery as regenerating breaking charge absorbers is amount of current a battery can handle without damaging itself is small compared to the current required to be drawn for a fast stop.

2.4 Ultra-capacitors

Ultra-capacitor technology is one of the growing technologies yet promising strengthens gaps in technology. It's has a capability to handle high currents makes it ideal for absorbing energy during regenerative braking. Researchers been done that ultra-capacitors can be used in parallel with battery banks to improve the battery banks current handling capability. An ultra-capacitor has design with electric double layer capacitors (EDLC) which capable store energy greater than the normal capacitor. It has two electrodes with micro porous and an electrolyte. The super-capacitor normally used as an alternative to pulse batteries and can draw a higher amount of currents without damage to itself. It has a life expectancy and cycle life about 50000 to 1000000 cycles compare to battery. But the energy density is relatively low in comparison. Energy stored in an ultra-capacitor can be calculated using [2]

Pc = 1/2 *C*V^2 V = the voltage across the capacitors terminals

C = capacitance

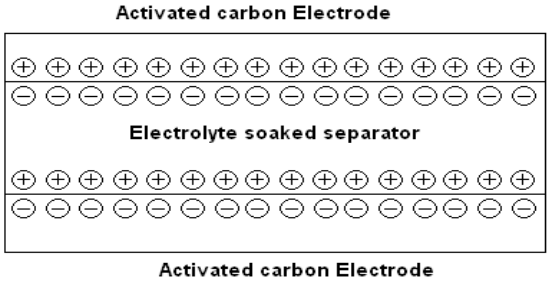

Figure 2.2: Ultra-capacitor layout

2.5 PWM controlling technique

PWM controlling technique is also one of the matted uses to control the switching invertors to control the brushless DC motor. This technique is a flexible controlling matted and also a batter protection for the switching invertors and motor. BLDC motor does not have a mechanical commentator and brushes instead while, it depending on electronic commentating circuit. Basically BLDC motor has three phases winding and required three phase inverter to control the speed. The HVIC gate drivers simplify the system design by eliminating three isolated power supplies and provide over current protection and protect the power device during supply under voltage condition. The PWM controlling matted not only will improve the speed and power losses in system it will also will increase the mean time between charge cycles of the battery [7]. The reduced losses also help reduce the weight of the system as smaller thermal management components are needed. These two factors are critical for portable equipment PWM control methods also enable novel control method and lever age the latest silicon and control methods, speeds above base speed can be achieved.

2.6 Journal review

2.6.1 Studies of Regenerative Braking in Electric Vehicle Author by Yoong, M.K.; Gan, Y.H.; Gan, G.D.; Leong, C.K.; Phuan, Z.Y.; Cheah, B.K.; Chew,K.W.

The research have been made on the how the principle of braking system function. It also explains how the braking energy used to store and utilizes back to minimize the energy losses in the electric vehicle. Basically, the braking system for electric vehicle establish on hydraulic braking technology. This type of braking will produce unclaimed heating during braking and cause a lot of energy wasted. This wasted energy can applied back to overcome the weakness of the vehicle and moreover it helps in saving energy and provide higher efficiency for electrical vehicle. When motor acts as a generator (regenerative mode) the motor will produce kinetic energy at the armature and the energy will be converted to electrical energy to restore the batteries or capacitor. During the

regenerative mode, the brake controller observes the speed of the wheels and calculates the torque and at the same time a wider energy produce from the rotational force will be covered into electrical energy and distribute to the batteries for storage. Today, the technology in automotive industry heading towards regenerative braking is improving the system. By using ultra-capacitor with added DC-DC convertor parallel with it had improve the regenerative and the electric vehicle performance. [4]

2.6.2 Regenerative braking system for electric bicycle based on DSP Author by Chih-Chiang Hua, Shih-Jyun Kao

In this research, regenerative braking recovery energy for electrical bicycle has been use to charge the battery. This system does not add any extra converter or ultra-capacitor. While, it been using only DSP(Digital Signal Processor) controller as a control unit. DSP controller far knows as tms320If2407 is a controller used to adjust the switching sequence of the inverter. The propose controlling this inverter so that the braking energy can be returned to charge up the battery. With the help of DSP control unit and regenerative braking energy recovery technologies, the braking energy that produce when motor acts as generator will be converted to electrical energy and return to battery. [5]

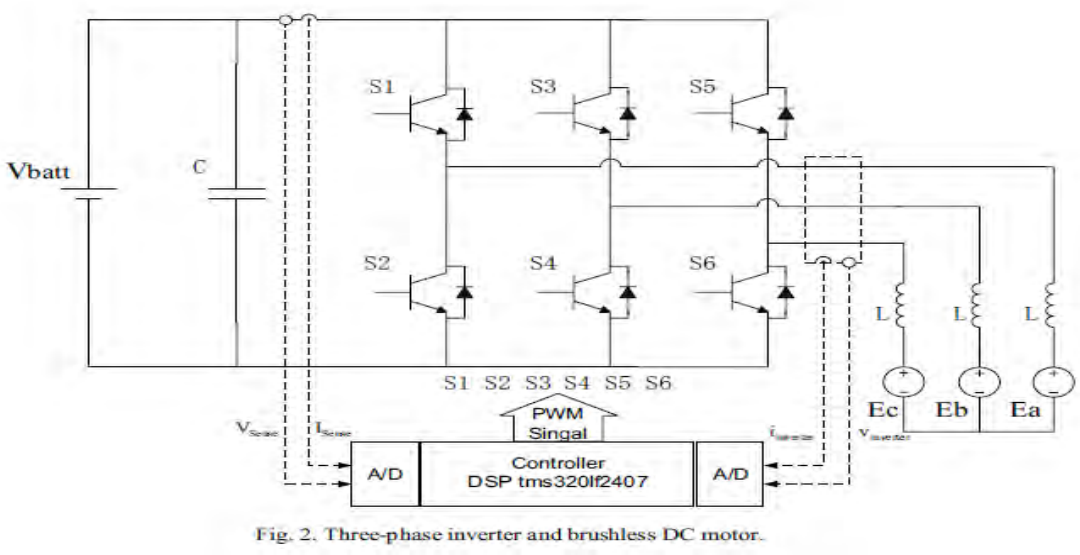

Figure 2.3: Three-phase inverter and brushless DC motor

The kinetic energy that produce at the armature of the motor when motor acts as generator will be converted to electrical energy by using DSP controller will be discuss in this research. When the battery power is send to drive the motor, the power will flow through the armature inductor and store the energy. The stored energy will make the armature current increase. When this happen, the current back EMF also will be increase making it to affect the performance of the battery charging in regenerative braking. To overcome this problem, the charge armature current will released by the discharge circuit mode.

Motor will be in generator mode when the system receives braking signal. The back EMF of the BLDC motor will be used to charge up the battery. However, there is problem using back EMF energy in this condition. The back EMF energy is still being less than battery power even if the motor generate at a higher rate. Moreover the current produce when power switching operation will be distribute to motor armature and will make the power at DC motor side bigger than the battery power. On this condition, the circuit will change mode similar with the boost convertor where the braking energy of DC motor will charge the battery. The changing mode of the inverter is controlled by DSP control unit. Through this regenerative braking storage, the system can improve the traveling range of the bicycles where the losses battery power has been minimize and the and also have improved the performance.

2.6.3 Fuzzy Logic Control in Regenerative Braking System for Electric Vehicle Author by Hao Zhang; Guoqing Xu; Weimin Li; Meilan Zhou.

The research has been made on regenerative braking energy recovery control system based on fuzzy logic control matted. Because of low energy produce when braking performance in regenerative braking energy recovering, this paper has establish a new method by using surgeon fuzzy logic controller(FLC) to improve this problem. This system got several inputs include the driver braking force, vehicle speed(torque performance), and battery SOC. One of the output will takes braking force form the regenerative braking energy. This system using a strategy on distributes regenerative braking force and frictional braking force sensibly during braking. This will make use of regenerative breaking features of a motor increase as much as possible. The increase of motor features will increase the kinetic energy as well and this energy can be converted to

be used as storage energy either in battery or ultra-capacitor. So this research tells that the fuzzy logic control matted can produce more braking energy and increase the overall electrical vehicle efficiency and also the system is more feasible to use. [6]

2.6.4 Research on the lead-acid battery and Ultra-capacitor Energy Storing System of Motor Vehicles Regenerative Braking Author by Chen Qing-zhang; Ma Wen-bin; Chen Xian-feng;

In this research, studied have been made on the lead-acid battery and ultra-capacitor. A two quadrant DC-DC converter have been place between the lead-acid battery and ultra-capacitor. The regenerative braking energy that produce when the motor acts as generator know as kinetic energy will be converted into electrical energy and is charge into an energy storing device so that it can be utilize back to provide extra energy to vehicle. The storing device that used in this system is the lead acid battery and ultra-capacitor. That system used the braking energy to charge the lead-acid battery and ultra-capacitor and the charge will be reuse back together with battery energy provide extra energy to the motor for power up. The regenerative energy can be store straight to lead-acid battery without using ultra-capacitor but system is using a ultra-capacitor. The purpose of using this ultra-capacitor because it can charge energy fast compare to lead-acid battery slow charges to store the braking energy. so by using this ultra-capacitor the extra energy that can't be achieve stored In lead-acid battery will be stored in ultra-capacitor. [7]

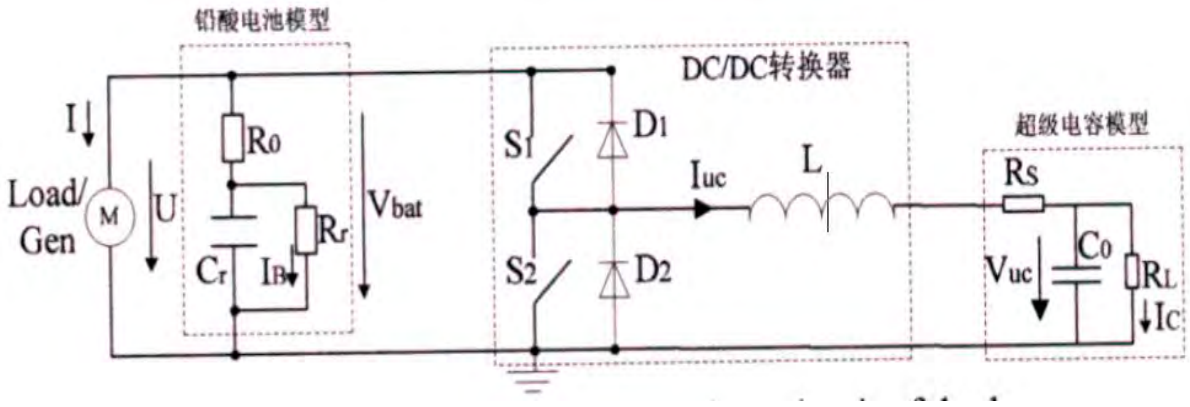

Figure 2.4: Structure sketch of implied equivalent circuit of duplex energy storing system

Figure 2.4 show the circuit diagram of the double energy system construct by using lead-acid battery, ultra capacitor and using two-quadrant DC/DC converter. The purpose use DC/DC converter is to control the barking energy so that the ultra-capacitor will be used fully to balance the vehicle load. Other than that, it will also limit the charge rate of battery to ultra-capacitor. The regenerative braking energy will charge the ultra-capacitor first. If the ultra-capacitor is not fully charged, the battery will help to full the charge. If the ultra-capacitor is fully charged, then only the battery will charge. When motoring mode, the energy will be supplied from both ultra-capacitor and battery in as same time together to energies to the motor and give the motor a greater wheel power to motor.

2.7 Power MOSFET

The creation of the power MOSFET was actually created due to limitation of bipolar power junction transistor (BJT) and it's become one of the popular and advance choices in power electronic application. The bipolar power transistor is one of the devices that use as a current controller. To run the device, it's requiring amount of one-fifth of collector current at the base to keep the device in ON condition. As it is too fast turn-off, it's requiring a high reverse current at the base of the device. Figure 2.5 and figure 2.6 below shows the schematic and symbol of the MOSFET.

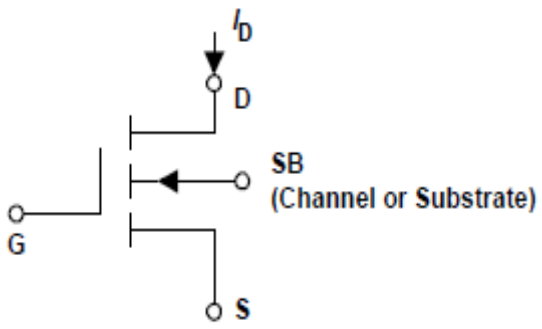

Figure 2.5: MOSFET symbol

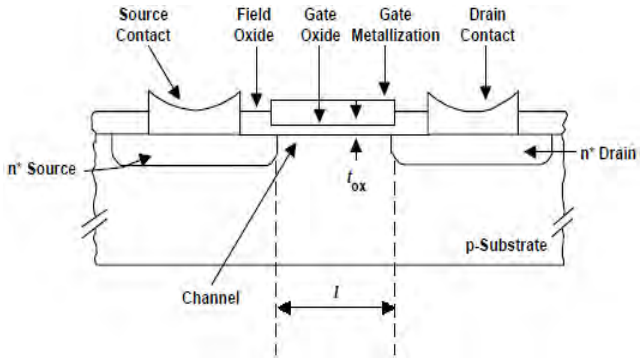

Figure 2.6: MOSFET schematic

The breakdown voltage, also known as BVdss is the voltages that reverse biased body diode breaks down and start the current to flow between the source and drain. It is