Snubber circuit designed for electric car drive system

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Abstract :- This article presents a method to develop the speed-controller dc-motor chopper drive system by using mosfet as the switching drive for motor speed control. The switching current during $t_{on\ state}$, and $t_{off\ state}$ of the mosfet can cause power dissipation. This can damage the mosfet. In addition, in the off state the mosfet is not conducted, there are some voltages across the mosfet that also can damage it when the voltage exceeds the mosfet voltage rating.This research therefore aims to study and design a snubber circuit for an electric car drive system that employs paralleled mosfet in order to control motor speed continuously under a heavy load.

Key-words: snubber circuit, mosfet, parallel connected, electric drive, chopper, power dissipation.

1. Introduction

To control the speed of a direct current motor, there are many methods [2],[4],[5] for example by adjusting the value of a large current capacity resistor. This method is durable and needs fewer devices; This method requires the high current capacity power electronic switch which can resist the instantaneous current during the switching times. The often used power electronic switchs at present are mosfet and IPM. At present, the IPM is a module that is mostly used in the electric car drive system; however, the drive circuit is expensive as well as the module itself. Consequently, this research is to present an 8 – paralleled mosfet electronic switch used as the drive circuit which is inexpensive and durable.

However, a major problem of the paralleled mosfet is the limitation of the current tolerant. To carry the load current for a long time by each mosfet switch alone can damage the whole drive system and cause overheat, or burst [1],[3].

This research is to study and design a snubber circuit for a motor drive system employing paralleled mosfet for the speed control [8]. The

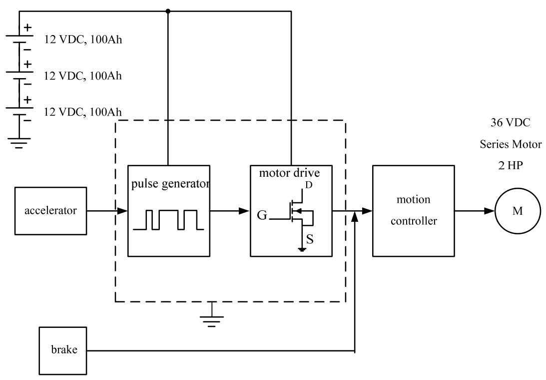

Fig. 1 Block diagram of Electric car drive system

Motor however, the high power loss is its disadvantage. Another method commonly used is to employ power electronic equipments as depicted in Fig. 1 drive system is inexpensive, requires less maintenance, and can be operated continuously when using a 2HP 36 VDC motor [11]. This article is divided into 4 parts, 1. Analysis of the drive system, 2. Design of snubber circuit, 3.Experiment, and 4. Conclusion.

2. Electric car drive system

A switching power electronic circuit used as the direct current motor speed control is depicted in Fig.2. The 8 mosfet switches are paralleled to control the electric car speed [9],[10].

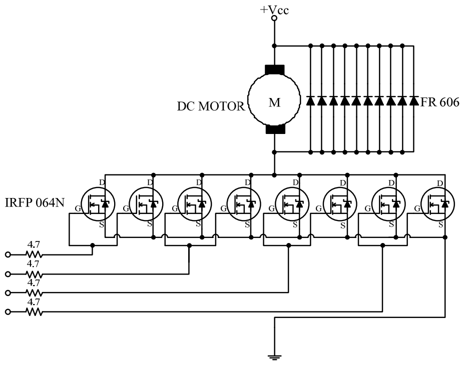

Fig. 2 Switching mosfet switches

However, the driving system has a major problem at the high load at $t_{on\ state}$ and $t_{off\ state.}$ While the mosfet conducts current as depicted in Fig.3, a large current flowing through the mosfet can cause damage due to the overheat. At the off state, a large amount of voltage is across mosfet, if the voltage across the mosfet for too long time, the damage due to the overheat can occur. Especially, for the paralleled case, each switch has a limitation of current tolerant; so, damage in one switch can affect the whole drive system.

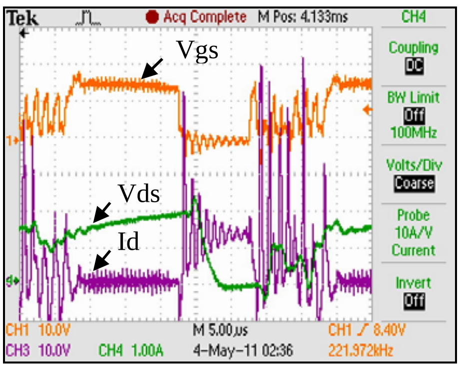

Fig.3 Voltage and current signals of Vgs, Vds, and Id from the experiment

3. Design of Turn-on and Turn-off Snubber Circuit

Due to the problem as mentioned above, the research aims to study and design a snubber circuit that is tolerant to over current or over voltage, and when there is the instantaneous change in both amplitude and rate of change.The designed snubber circuit has been divided into 2 sections[6],[7]: the over current protection and the over voltage protection. The details of each section are as follows;

The over voltage protection (turn-off snubbers) is depicted in Fig.4. To protect the circuit from the instantaneous voltage, a resistor is serried with a capacitor and then paralleled with the mosfet which is called a snubber circuit. The resistor and capacitor parameters can be calculated by

$$\text{capacitor } C_{S1} = \frac{I_o t_{fi}}{2V_d}, \quad \text{resistor } R_S < \frac{t_{onstate}}{2.3C_S}$$

where

C_{S1}	Snubber Circuit Capacitor
I_o	Motor current at starting of a 200 kilograms load, 60 A
$t_{fi} \approx t_{ri}$	$t_{off\ state}$ of the mosfet which is around the starting time
V_d	Motor rated voltage 36 volt
R_S	Snubber circuit resistance
$t_{onstate}$	Current conducting period
2.3	Time interval the capacitor can totally discharge

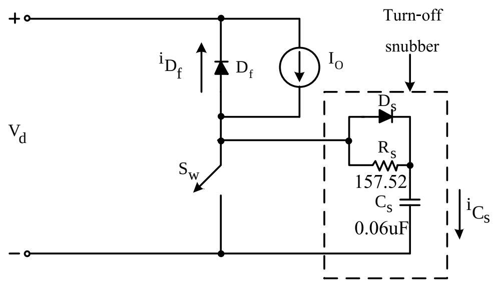

Fig.4 Over voltage protection circuit

However, a diode should be connected parallel with the resistor for the recovery time of the snubber circuit.

Under the surge voltage, the diode will conduct the current to pass through the capacitor. The capacitor will then behave like it is operating under the short circuit, which help reduce the voltage in the snubber circuit by allowing the voltage to be over itself. Under a normal operation that the capacitor is charged, the current will pass through the mosfet. When the capacitor is fully charged, the current will stop passing through the capacitor but it will flow through the whole circuit,

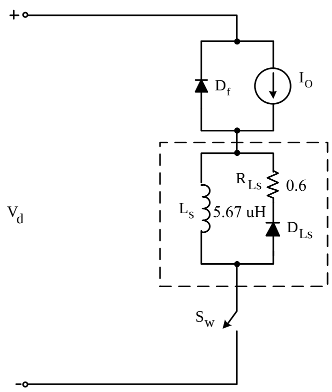

Fig.5 Over current protection circuit

the diode, and the resistor. The resistor helps reduce the current oscillation and limits the current under the current conducting period. However, at initial the capacitor will discharge the current into the circuit and the diode will help reduce the instantaneous current at the recovery.

To design the over current protection circuit (Turn-On Snubbers), the initial current (di/dt) is high and greatly damages the circuit system, therefore, as depicted in Fig.5, an inductance (L_s) is serried with a drain gate to reduce the rate of current. The energy is stored in the inductance and then will be transformed into heat. The inductance value can be calculated by

$$\text{resistor} \quad R_{LS} = \frac{V_d}{I_o}, \text{ inductor} \quad L_S < \frac{t_{offstate}}{2.3} R_{LS}$$

where

L_S	Snubber Circuit Inductance
$t_{offstate}$	Current conducting period
$t_{fi} \approx t_{ri}$	$t_{off\ state}$ of the mosfet which is around the starting time
R_{LS}	Snubber Circuit Resistance
V_d	Motor rated voltage 36 volt
I_o	Motor current at starting of a 200 kilograms load, 60 A
2.3	Time interval the capacitor can totally discharge

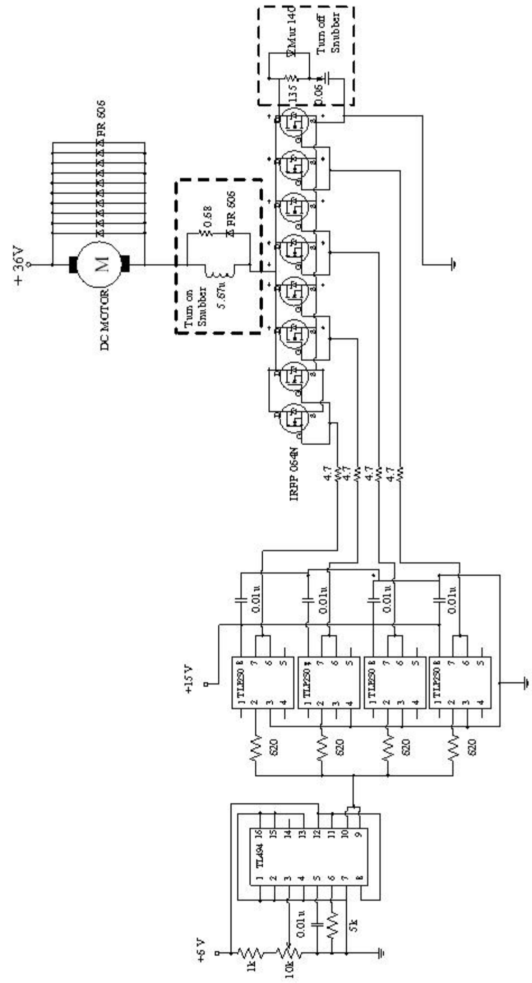

Fig.6 The equivalent circuit of the system

4. Experiment

The experiment is conducted by connecting a snubber circuit with a motor speed control circuit of an 2 HP electric car rated as depicted in Fig.6 and Fig.7.

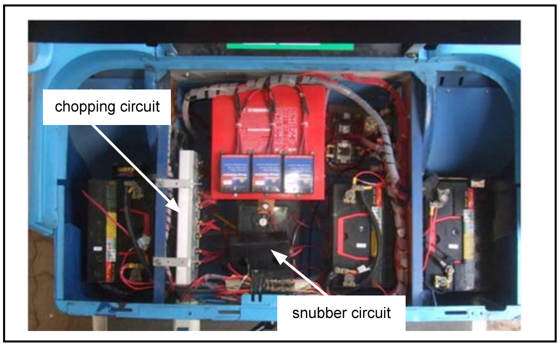

Fig.7 The electric car drive system of 2 HP 36 VDC rated

The duty cycle of a square wave pulse generating circuit can be adjusted through the 10kΩ

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resistor. The output pulse of the circuit then will be amplified and used to control the switching circuit; therefore, the motor voltage is able to change and vary according to the duty cycle of the square wave pulse generating circuit.

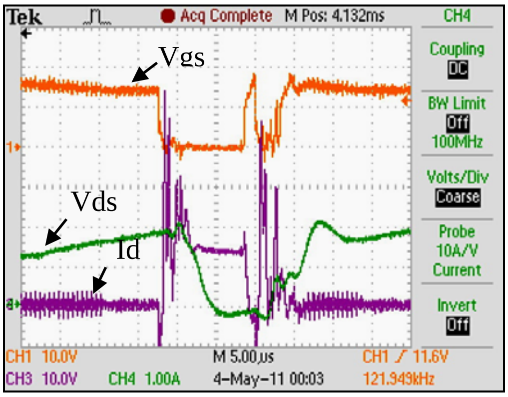

Fig.8 Signals of Vgs, Vds, and Id after connecting Turn on, Turn off Snubber circuits

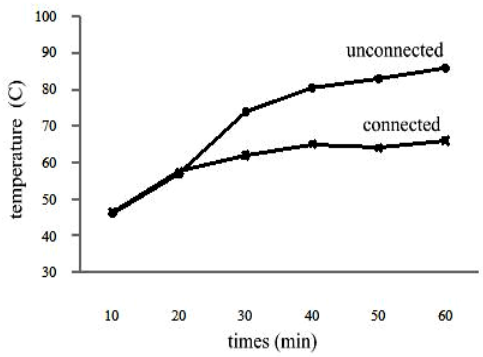

Fig.9 Comparison of temperature (heat) on the mosfet

The experiment results under adjusting the duty cycle of motor are depicted in Fig.8, and the comparison of heat stored in the mosfet is depicted in Fig.9.

5. Conclusion

From the experiment of the system after connecting the designed circuit, Turn On Snubber and Turn Off Snubber Circuits were observed for the Vgs and Vds of the mosfet under various duty cycles. The result of the experiment shows that whether the designed circuits are connected the overlapping of the voltages is low. However, the signals Vgs, Vds, and Id perform better responses when the designed circuit is connected, especially the Id that is decreased apparently, which helps reduce loss in mosfet while conducting the current. Besides, the voltage Vp that is able to damage the mosfet can also be reduced. Consequently, it can be concluded that to yield the best efficiency of the switching circuit, both of the snubber circuits should be connected.

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