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Development of the Electric Drive System for Electric Vehicles.

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ABSTRACT

DC series motor has been widely applicated in industry due to many advantageous characteristics , such as high starting torque, easy construction of its controller, and cost economy, etc.. However, by high starting current , excessive surge voltage, and so on, many problems which could make engineers relinguish to use it are induced.

In this paper , various protection methods for power circuit are discussed. Particularly, a new proposed snubber circuit which consists of two diodes , one capacitor, and a resistor increases the performance with respect to the suppression of the surge voltage. Furthermore, the plugging algorithm , by checking the armature current and voltage and controlling the field coil current , is designed and implemented. Also , these methods and algorithms were applicated in electric vehicle , and we could find its stability to be considerably improved.

I. INTRODUCTION

One of the environmental problems facing the Korea today is air pollution.It is factual to say that automotive emissions in various forms are one of the principal contributors to the air pollution problem in the metropolitan areas. So, although the size, weight, and cost of presently available fuel cells or batteries have prevented their use in commercial passenger cars, the electric car has been proposed , researched , and developed for the solution of the above mentioned problem from the beginning of 1980's. And the guidelines for such a development included the followings:

1. The performance of the electric vehicles must equal or exceed that of an equivalent modern automobile with the internal combustion engine.
2. The electric drive system must operate from batteries or fuel cells presently available.
3. The operator controls must be the same as those of a present day car , that is , the ignition key , accelerator pedal, forward, reverse, etc..

Also, it was agreed that the electric vehicle should operate without a gearshifting transmission.

In this paper, as a part of the development of electric car , DC series motor drive system for the electric fork lifter is discussed. At first , the chopper with snubber circuit , shown in Fig. 1, and a method of plugging are described. And next , the various fault-detecting algorithms and the indicator for that are presented.

II. ELECTRIC DRIVE SYSTEM

Figure 1. shows a simplified diagram of the major components of the electric drive system powered from a static DC series motor to produce the desired torque and speed through the chopper. The driving current of the switching device is determined predominantly by the vehicle weight and acceleration requirement and the battery voltage. Motor details, control strategy,

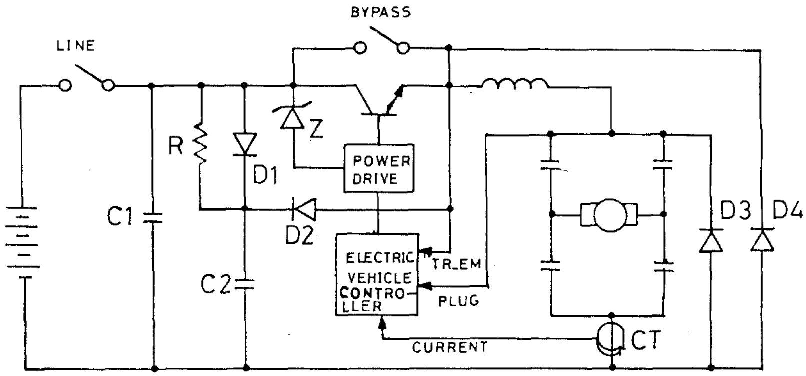

Figure 1. Simplified diagram of the electric drive system

and drive-train mechanical details, except for efficiency values, are not needed to determine the approximate current of the chopper. It can be calculated by using the following formula: [2]

$$I = 1.356*(W*a*v)/(g*Vb*n) \qquad (1)$$

here I = average chopper current(A)
W = vehicle weight (lbs)
a = maximum required acceleration (ft/s**2)
v = maximum velocity (ft/s)
g = acceleration due to gravity (32.2 ft/s**2)
Vb = average battery voltage (V)
n = average drive train per unit efficiency

In our system, W= 9600 (lbs) including full loads, a= 1.5 (ft/s**2) which corresponds to 0 to 9.1ft/s in 6 sec, v =9.1 ft/s, Vb=48volt. and n =0.71, therefore, solving for I using equation (1) gives I= 162 A. But, by the consideration of the wind, rolling resistance and so on, the chopping current may be about 200 Amperes.

Also, The fast falling time of collector current in high-current transistors can give rise to relatively a significant " L di/dt effects " in stray wiring or layout loops. and due to this effect, high-power Zener diodes (Z1 in Fig. 1) were required to connect in parallel with the transistor module to avoid damage from transient voltage spikes due to wiring inductance.

Moreover, it is necessary to connect a snubber circuit across a power switching device to absorb the energy associated with the recovery current in the device and limit the resulting voltage spike, Figure 2, and the rate of rise " dv/dt ". And, a snubber circuit plays on important role in determining the full capability of a high-power switching device.

1. Design of Snubber Circuit

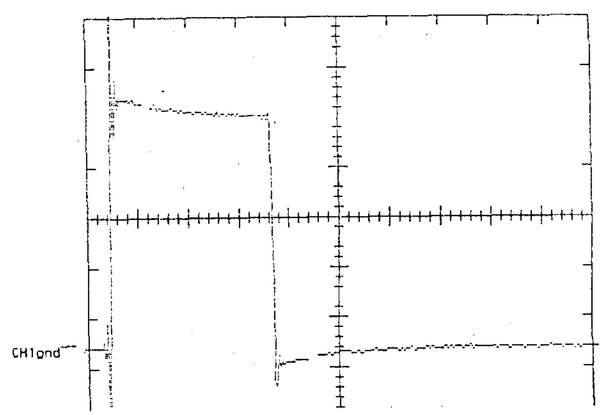

Figure 2. Waveforms during turn-off

In figure 1, C2 can be calculated by following equation:

$$C2 = l*(Io**2)/(Vcep-Vb)**2 \qquad (2)$$

here Io = maximum turn-off current of transistor
l = battery and stray wiring inductance
$Vcep$ = maximum voltage between emitter and collector
Vb = battery voltage

For the determination of R2, the following inequality

(3) is used.

$$R < 1 / (2*3*C2*f) \qquad (3)$$

Here f = switching frequency

But, R2 should be selected as large as possible to minimize the trapped energy during turn-off and the consequent losses.

During turn-on, voltage spike at transistor-emitter, shown Figure 3, causes the reverse-biased secondary breakdown or makes the switching device vibrated undesirably. Assuming that the maximum turn-on current of transistor is the same as the maximum turn-off current, the spike can be reduced by using a single diode, D2.

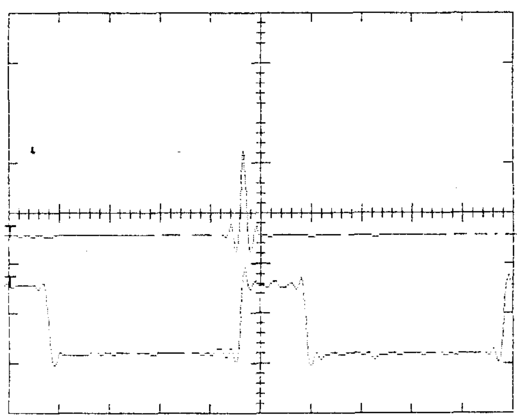

Figure 3. DC power-line and votage waveform of TR-emitter during turn-on

2. Plugging method

Assuming that a motor drives a load in a forward direction and the electrical connections of the motor are changed to reverse, at least for some time , the mechanical system will be driving the motor in a direction opposite to that which would result from its own developed torque. In that case, the sudden change in direction, in a car , causes some dangerous conditions to operators and passengers. So, for the operator's safty , the mechanical system with a large inertia, sould mount carefully a plugging method as a following procedure.

1) Change the electrical connections soon after the reverse direction was commanded from operator.
2) Check the plugging port , shown in figure 1 , and if negative voltage, lower the current limit value and turn on power-transistor.
3) When the plugging bit is posistive, turn off TR and increase gradually the turn-on duty of TR.

III. FAULT DETECTION and DISPLAY

Faults such as the transistor breakdowns and the brush-weaken of motor are detected as follows.

At first, check the transistor-emitter voltage. If it comes into always low-voltage (about zero voltage) while the output of PWM is being commanded, the transistor must be destroyed in the open state. But, if it is held up always the high voltage (about 48 volt.) , the transistor may be broken down as the short.

Because the transistor breakdown in the open state or the short hazards the operator and the system , the system shoud be prevented from operating the car.

Also, the brush-weaken and the overheat of the motor and controller can be detected , indicated to operator, and managed properly. The indicator, shown in figure 4, uses a LCD device.

IV. CONCLUSION

The motor drive system for a vehicle, described in this paper, is implemented in an electric fork lifter,

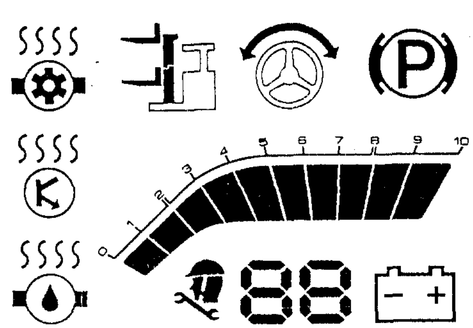

Figure 4. Indicator using LCD

and tested continuously for about 1000 hours. At present, its field-test is being processed. In the test, no errors have been occured. When faults are issued, diagnosis functions, not described in this paper, give us easy-maintenance. Consequently, this system has the high stability due to the various protections. To further advance the vehicle system, AC induction motor should be studied.

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