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PROTECTION OF DC MOTORS FROM FIELD FAILURE – A SURVEY

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Abstract: Field failure protection of dc motor has gained a great demand as it's a topic of essence. Purpose of field failure relay is to protect the motor from the damage of field failure. This paper presents a comprehensive review of various methods of speed control and field failure protection. Firstly, the principles of op-amp and chopper will be briefly presented. Secondly, the employment of the op-amp in a field failure protection will be outlined. The concept of op-amp in field failure protection can be extended for application to different DC motor such as: series, separately excited and permanent magnet DC motor.

Keywords: DC motor; field failure protection; operational amplifier.

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INTRODUCTION

Direct current (DC) motor has already become an important drive configuration for many applications across a wide range of powers and speeds. The ease of control and excellent performance of the dc motor will ensure that the number of applications using them will continue grow for the foreseeable future.

The use of power electronics for the control of electric machines offers not only better performance caused by precise control and fast response, but also maintenance, and ease of implementation. In parallel with the advance in power electronic there have been great advance in microcontroller-based control systems due to the microcontroller flexibility and versatility. This is because all the control algorithms are implemented in software [].

Operational amplifiers had their origins in analog computers, where they were used to do mathematical operations in many linear, non-linear and frequency-dependent circuits. Characteristics of a circuit using an op-amp are set by external components with little dependence on temperature changes or manufacturing variations in the op-amp itself, which makes op-amps popular building blocks for circuit design. Op-amps are among the most widely used electronic devices today, being used in a vast array of consumer, industrial, and scientific devices. Many standard IC op-amps cost less in moderate production volume; however some integrated or hybrid operational amplifiers with special performance specifications may cost high in small quantities. Op-amps may be packaged as components, or used as elements of more complex integrated circuits.

With the proper external components, the operational amplifier can perform a wide variety of “operations” on the input voltage. It can multiply the input voltage by nearly any constant factor, positive or negative, it can add the input voltage to other input voltages, and it can integrate or differentiate the input voltage. The respective circuits are called amplifiers, summers, integrators, and differentiators. Op-amps are also used to make active frequency filters, current-to-voltage converters, voltage-to-current converters, current amplifiers, voltage comparators, etc. These little parts are so versatile, useful, handy, and cheap that they’re kind of like electronic Lego blocks — although somewhat drably colored.

A customizable microcontroller incorporates a block of digital logic that can be personalized in order to provide additional processing capability peripheral and interfaces that are adapted to the requirements of the application.

DC motors are main building blocks in different industries. Their malfunction will not only lead to repair or substitution of the motor, but also effect major financial losses due to unpredicted process downtime. Reliable protection of dc motors is essential for reducing the motors malfunction rate and prolonging motors life. If the main field of a shunt motor or a compound motor is extremely weakened or if there is complete loss of main field excitation, a serious damage to motor can occur under certain condition of operation. Since the speed of a dc motor is inversely proportional to flux, its speed tends to rise rapidly when the flux is decreased. If the field failure occurs the armature will draw heavy current (as good as short circuit condition), the motor speed will rise dangerously high level.

Conventional dc motor field failure protection techniques are not so effective and simple as compared to state-of-the-art of highly efficient Power Electronic based protection system. In this paper not only field failure protection system but also the simple speed control operation is presented.

Any dc machine needs to operate is supplied with dc voltage. Typically this voltage has to be produced starting from the ac supply voltage. DC machines usually are not satisfied with the voltage obtained by simple filtration and recovery, requiring a continuous variation of it. Continuous change of the supply voltage can be done by changing the ac voltage through autotransformers before rectifier or after rectifying ac voltage through static converters in commutation.

Modern devices that are equipped with power supply on the principle of PWM switching are known in the literature under the names of CHOPPER or SWITCH MODE POWER SUPPLY.

The chopper is controlled commutation converters, which use in the force thyristors provided with extinguishing auxiliary circuits or completely controlled devices. Control of these devices, both the entrance time and for blocking their conduction is achieved only at well-defined points in time, hence the named as controlled commutation converters.

Using chopper as a converter the speed of dc motor is controllable. The chopper firing circuit gets signal from controller and then by supplying variable voltage to the armature of the motor the desire speed chopper can be achieved.

The class E chopper/ four quadrant chopper is made of four single quadrant choppers connected H- Bridge, and four anti-parallel diodes connected also in H- bridge. Circuit configuration ensures current circulation from the source to the dc motor and from the machine to the power supply in case of the generator regime.

I. literature survey

DC motor speed controllers are very useful for controlling the motion of robotic and industrial automation systems. DC motor can provide a high starting torque and it is also possible to obtain speed control over wide range. For precise speed control of servo system, closed loop control is normally used. The speed, which is sensed by sensing device, is compared with the reference speed to generate the error signal and to vary the armature voltage of the motor. There are several controllers that can be used to control the speed of the motor such as by using thyristor. Phase-locked-loop control, chopper circuit, fuzzy logic controller and etc. some of the technique are surveyed below.

The basic principle behind dc motor speed control is that the out speed of dc motor can be varied by controlling armature voltage for speed below and up to rated speed keeping field voltage constant. The output speed is compared with the reference speed and error signal is fed to speed controller. Controller output will vary whenever there is a difference in the reference speed and the speed feedback. The output of the speed controller is the control voltage that controls the operation duty cycle of converter. The converter output give the required voltage to bring motor back to the desired speed. The reference speed is provided through a potential divider because the voltage from potential divider is linearly related to the speed of the dc motor. The output speed of motor is measured by Tachogenerator and since Tacho voltage will not perfectly dc and will have some ripple. So, a filter is require with a gain to bring Tacho output back to controller level [6].

The 68HC11E9 microcontroller implements the control algorithm by conditioning the speed and current signals and performs the speed regulation according to speed reference fed through the keypad [1]. May be as advance in power electronics there have been great advance in microcontroller-based control systems due to the microcontroller flexibility and versatility. This is because the entire control algorithm is implemented in software [1]. This work uses an optical encoder to measure the speed of motor and the current sensing was accomplished by using Hall Effect current sensor. It senses the current signal to microcontroller.

The use of stand-alone microcontroller for the speed control of dc motor is gaining ground. Nicolai and Castagnet [5] have shown in their paper that how a microcontroller can be used for speed control. The operation of the system can be summarized as: the drive from a rectified voltage, it consists of chopper drive by PWM signal generated from a microcontroller unit. The motor voltage control is achieved by measuring the rectified mains voltage with the analog to

digital converter present on the microcontroller and adjusting the PWM signal duty cycle accordingly [1].

Another system that uses a microprocecessor is reported in the work of Khoel and Haddi [2] a brief description of the system is as follows: the microprocessor computes the actual speed of the motor by sensing the terminal voltage and current, it then compares the actual speed of the motor with the reference speed and generates a suitable control signal which is fed into the triggering unit. This unit drives a H-bridge Power MOSFET amplifier, which in turn supplies a PWM voltage to dc motor [1].

Chauhan and Semwalhas presented in paper [3] that a PMW based speed control of DC motor through RS232 with PC goal of this as Role of electrical drives in a major concern in industrial automation. The work deals with utilization of DC motor for various applications by controlling the speed and orientation according to the field of interest. Pulse Width Modulation (PWM) is utilize for switching devices to produce the effect of continuously varying analog signals.

Afanasov states that a simple speed control method which is based on operation principle of chopper, it transfer a constant a voltage in pulse train, usually rectangular, whose duration and / or frequency can be changed by command, so the average voltage result are adjustable. [4]

PWM is an entirely different approach to control the speed of a DCmotor. The paper states, that power is supplied to the motor in square wave of constant voltage but varying pulse-width or duty cycle. Since the frequency is held constant while the on-off time is varied, the duty cycle of PWM is determined by the pulse width. Thus the power increases duty cycle in PWM. Therefore with basic concept of PWM and H- bridge the direction And the speed of motor can be controlled[6].

The full report provides the background and with regard to protecting motors controlled by adjustable speed drives(ASDs). The intent is to provide guidances for the protection application engineer to implement adequate motor system protection given the special electrical conditions found on the output of a drive.[7] DC motors are identified as adjustable speed machines for many years and a wide range of options have evolved for this purpose.

Adjustable speed AC drives would be more complex and expensive. D.C motor is considered as a SISO (Single Input and Single Output) system which has torque/speed characteristics and is compatible with most mechanical loads. By proper adjustment of the terminal voltage [9] the mentioned characteristic makes a D.C motor controllable over a wide range of speeds. In this article controlling DC motor speed using Chopper as power converter and PI as speed and

current controller is investigated. A chopper is a static power electronic device that converts fixed dc input voltage to a variable dc output voltage. Chopper systems have smooth control capability and are highly efficient and fast in response. A chopper can be used to step down or step up the fixed dc input voltage [8] like a transformer.

Adjustable speed drives may be operated over a wide range by controlling armature or field excitation. Speeds below rated by armature voltage control and above rated using field excitation variation, development of various solid state switching devices in the form of diodes, transistor and thyristor along with various analog/ digital chips used in firing/ controlling circuit, have made dc drives more accessible for control in innumerable areas of applications[].

II. Addition

A low cost protection of dc motor from field failure and also simple speed control method can be implemented. Which would consists of field failure relay (i.e. the operational amplifier and micro controller) which would cut armature from the main circuit and the motor is saved from its effects. On the other hand, the class E chopper can not only be used for speed controlling in different direction but also for braking. This system can be extremely suitable for detecting/ sensing absences of field current, directional reversal, speed control, soft starting.

It would roughly consist of a rectifier and filter circuit to convert ac supply into dc and to remove ripples from dc signals respectively.

During the abnormal conditions, the operational amplifier would send the signals to the microcontroller and the supply to the armature, would be tripped using class E chopper (H-bridge).

During the normal condition, the function of H-bridge will be to reverse the direction of motor rotor and the supply to the armature in fault condition will also break.

Hence dc motor can be prevented from the damage of field failure and direction reversal of the motor with speed control to certain extent can be achieved.

In additional various control keys can be provide such as start, stop, reverse motoring, reverse braking, forward motoring, forward braking. Using these keys the user may set the motor to run in any one of the above mentioned modes.

VI. CONCLUSION

Survey has been provided of speed control techniques, adjustable field system, and field protection. Application of speed control and protection of field failure in dc motor will continue to gain in the near future. Most promising applications are those whose use don't change the performance of the dc motor but enhances it.

Along with survey a simple field failure can be implemented based on principle of operational amplifier which can be combined with microcontroller. Using class E chopper i.e. H-bridge as simple motor rotor direction reversal.

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