APPLICATION CONSIDERATIONS FOR ADJUSTABLE VOLTAGE AC SCR MOVABLE BRIDGE DRIVES

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ABSTRACT

For many years the adjustable voltage ac silicon controlled rectifier (SCR) drive has been the standard drive specified on movable bridges. The evolution of this drive from its earliest beginning to a movable bridge standard is traced.

The application of this drive is examined with respect to motor requirements, speed regulation, torque capabilities and stopping methods. Various types of SCR speed regulated primary voltage control, as well as non-speed regulated controls, are compared for performance as movable bridge drives. Other considerations for selection of controls for movable bridges are presented.

Finally, a discussion of what the future holds for adjustable voltage ac SCR controls is discussed. Should this control remain a bridge standard?

INTRODUCTION

Many movable bridges have used adjustable voltage ac silicon controlled rectifier (SCR) drives for 20 years. This came about because of a desire to eliminate the routine maintenance associated with magnetic contactor type control.

Adjustable voltage ac SCR drives work on most bridge applications regardless of whether the load is overhauling or non-overhauling. Fairly accurate positioning can be obtained by speed-regulating the drive. As with many things, people are reluctant to change from a system that has proved as versatile as adjustable voltage ac SCR control. However, technology has advanced in the last twenty years.

Many types of electrical span drives have been used throughout the years on movable bridges. Fifty years ago it was quite common to use manual drum controllers (Figure 1). These were usually a plain reversing type. Although simple and easy to troubleshoot and maintain, this type control provided very limited torque and speed control. The amount of secondary resistance in the wound rotor motor was under direct control of the operator and it was necessary for the operator to advance the drive manually from point to point. Some degree of speed control was possible as long as the load was not overhauling. In an overhauling condition, movement of the controller handle to a slower speed point resulted in a faster speed of the bridge (Figure 2). Slowdown or stopping could only be accomplished by plugging the motor or by application of a mechanical brake. The mechanical drive system of the bridge had to be sized to accept the maximum torque of the motor or brakes.

With the advent of magnetic control, more sophistication became possible in controls for bridge drive systems. Also, timers and other devices could be incorporated in the controls to relieve the operator of providing the acceleration time delay. Several types have been utilized - depending on the mechanical parameters of the bridge.

Plain Reversing

Provides speed torque characteristics similar to the manual drum controller (Figure 2). Used on bridges that typically do not have overhauling load or that have a load brake. Slowdown or stopping was possible only by plugging or coasting. Automatic plugging to stop or slowdown schemes was sometimes utilized.

Counter Torque

Used on bridges that typically have an overhauling load in one direction (lift, bascule). The motor is connected in the opposite direction to the direction of travel with considerable slip resistance in the circuit. Speed torque curves provide several speed points to select from under varying load conditions (Figure 3). This type control provides poor speed regulation under varying load conditions, but does provide good slowdown and stopping characteristics. It has been used infrequently on movable bridges.

AC Dynamic Lowering

Used on bridges that have overhauling loads in one direction. Two phases of motor are connected to one incoming line phase. This type control provides speed characteristics dependent on load. It provides poor slowdown and braking characteristics (Figure 4). Used infrequently on movable bridges.

DC Injection

Used on bridges with and without overhauling loads. Provides good slowdown and stopping characteristics under varying load conditions.

This type control has been used considerably on movable bridges, it is sometimes called dc dynamic braking. DC is injected into stator circuit of motor with the ac disconnected. Slow, stable speed can be provided under overhauling load conditions (Figure 5). Good slowdown and stopping characteristics are also provided under any load condition (Figure 6). It can be seen from this curve that dc injection provides initially low braking torque that builds up to a maximum around 10% speed and then quickly falls off to zero. The controller is basically a plain reversing type with dc being provided by a rectifier. The incoming ac is removed from the motor and dc is injected into the motor only when slowdown or stopping is desired, or when operating at reduced speed with an overhauling load.

Eddy Current Brake

This type control uses an eddy current load brake to provide slow, stable speeds under any load condition and to provide slowdown and stopping torque (Figure 7). The controller is basically a plain reversing type with fixed or variable excitation being provided to the eddy current brake. The eddy current brake provides loading to the motor in a non-overhauling load condition to provide slow, stable speeds. During slowdown and stopping or if an overhauling load condition exists, the eddy current brake provides braking torque. Eddy current brake control provides excellent characteristics for bridge applications, but has not been used extensively on bridge applications. This is because of the logistics of mounting the eddy current brake (Figure 8).

Synchro-tied Motor

Used mostly on lift bridge to maintain the positioning of each side of bridge. Power is transferred from one motor to the other to maintain the speed of each motor by tying the rotors together. Compensates for inherent differences in the basic motor characteristics and loading. Slowdown and stopping or speed control must be supplied by another means. This type control is used frequently on special bridge applications.

As can be seen from the preceding, magnetic control provides a variety of control characteristics for varying bridge applications. Magnetic control is relatively easy to maintain and troubleshoot. However, more routine maintenance (contact tips and coils) is required.

In the late 1950's the first solid state controls became available. Saturable reactors were used to provide primary voltage control of ac induction motors (Figure 9). Accurate slowdown and positioning of the bridge became possible because of speed regulation (Figure 10). A reference control signal was compared to a tachometer signal and the primary voltage was increased or decreased to maintain the desired speed. Ramping of the speed reference provided a torque-limiting function, under normal operating conditions. Massive reactors required space and were inherently slow to respond. Most routine maintenance was eliminated because electro-mechanical devices were kept to a minimum. It was the forerunner of a system that has been a widely accepted bridge standard for 20 years.

By the middle 1960's silicon controlled rectifiers (SCR) began to replace the reactors. This was a second generation solid state control that offered advantages over the saturable reactor controls. These advantages were:

1. Massive expensive reactors were eliminated .

2. Many of the adjustments were eliminated.

3. SCR controls required almost no routine maintenance.

4. Modular electronics with indicating lights and other troubleshooting aids reduced troubleshooting and serviceability problems.

Both contactor reversing and SCR reversing types have been used on movable bridges. Many spefications still call for contactor reversing types, even though solid state reversing types offer the advantage of quicker response and less mechanical devices to maintain.

The basic operation of an SCR primary voltage drive can be described as follows (Figure 11):

1. A ramped signal is produced by the ramp function generator (RFG). Both the rate of increase of the signal and the ultimate magnitude of the signal can be controlled by pot adjustments. An increasing or decreasing ramp can be produced by the ramp function generator.

2. The speed reference signal is compared with the tachometer (TACH) feedback voltage in the signal comparator module (SC). The signal comparator determines which thyristor should be turned on and initiates a permissive signal. The signal comparator also determines what portion of the cycle the thyristors must conduct in order to produce the proper motor voltage and speed, and initiates a speed error signal into the pulse generator module. Shielding for the tachometer leads may be required to prevent noise from being introduced into the system.

3. The pulse generator module (PG) combines a phase-synchronizing voltage (from the three power supply/synchronizing transformers) and the adjustable error signal (from the signal comparator module) to produce pulses which fire each of the thyristors at the proper portion of the half cycle. In a three phase system, each phase voltage is displaced in time by 120 electrical degrees. Hence, the instant of firing is different for each thyristor. Consequently, there must be a separate pulse circuit for each thyristor.

4. Each pulse produced by the pulse generator is amplified by a pulse amplifier module (PA).

5. The pulse former module (PF) controls the magnitude and shape of the firing pulses.

6. A phase sequence module (PI) to indicate proper incoming line sequencing and a power supply module (PS) to provide dc voltage for the electronics in the system are provided.

A number of subjects must be considered when applying ac SCR drives to movable bridges. Motor selection and considerations are important. NEMA D squirrel cage motors have suitable speed torque characteristics for use as bridge drive motors. However, wound motor motors provide more flexibility. Sometimes, after a bridge drive is installed, it is desirable to reduce the full speed of the bridge for mechanical or electrical reasons. Speed reduction from motor rated speed can be achieved by the use of slip resistance with a wound rotor motor instead of phasing back the stator voltage. This results in a reduction in motor heating. The effect of reducing the primary voltage is to reduce the strength of the rotating magnetic field in direct proportion. The currents induced in the rotor are directly proportional to the stength of the rotating magnetic field. However, the torque produced is proportional to the voltage squared. For example, if we apply 90% of rated voltage, the current will be reduced to 90% but the torque will be reduced to 81%. Therefore, less torque is produced per unit of current when primary voltage is reduced. If we reduce the torque by the use of slip resistance, the torque and current remain in relatively the same proportions. However, in practice, motor heating is seldom a major consideration on movable bridges. Most bridges have a very limited number of operations in a 24 hour period. The total travel time on most bridges is measured in several minutes and bridges are normally considerably overmotored. Even if we exclude the motor heating aspect of this issue, the wound rotor motor is less costly and more readily available than a NEMA D squirrel cage motor. Also on bridge drives with more than one motor, inherent differences in the motors and systems can be compensated for, somewhat, by adjusting the slip resistance.

Most movable bridges are considerably overmotored to provide for rapid acceleration of massive loads. AASHTO 2.5.4 requires that bridge machinery be designed to handle 150% of the motor full load torque. Since wound rotor and NEMA D motors are capable of supplying a maximum torque of 275% of motor full load torque, consideration must be given to limiting the motor and brake torque to prevent mechanical damage to the bridge drive machinery. Several methods are used to limit torque on SCR adjustable voltage drives:

1. Ramping of the reference signal is used to provide an adjustable rate of acceleration. The drive reference signal is increased along a linear ramp and compared to the tachometer signal. Only enough torque is produced to match the rate of acceleration to the desired rate of acceleration. The total time is adjustable and the rate of acceleration can be adjusted to provide the proper amount of torque under most load conditions.

2. Limiting of the firing angle to prevent a mechanical or electrical failure from causing excessive torque to be produced by the motor. Firing angle limits are usually limited in their time duration.

3. Limiting current to prevent excessive torque from being produced. A current transformer can be used to monitor motor currents and phase back on the firing angle if excessive current occurs.

4. Mechanical torque limiting devices are also being used to limit torque on movable bridges. Slip clutches and other methods provide backup to the controller torque limiting devices to prevent excessive torque from being transmitted to the machinery.

Most movable bridge drives provide speed regulation to accurately position movable bridges under any load conditions. A typical movable bridge duty cycle might consist of (Figure 12 Typical Duty Cycle):

1. Ramping and traveling at slow speed to insure that the bridge has cleared any obstructions.

2. Ramping and traveling at full speed to the near open or near closed position.

3. Ramping and traveling at slow speed to a near open or near closed position.

4. Jogging, ramping, coasting or braking to a stop.

5. Setting of brake before or after the motor is disconnected.

The limit switches must be properly positioned to provide for excellent repeat accuracy. Normal, windy and icy conditions must all be taken into account when positioning limit switches. Positioning or stopping the bridge from a predictable slow speed and in the same distance is easier than from an unpredictable faster speed. Final limit switches must be positioned to allow for reaction time of the device used to stop the bridge. Instantaneous stopping of massive bridges is not possible from any speed.

A multi-motor bridge can also be an important consideration in the selection of an SCR adjustable voltage drive. Because of the inherent speed regulation of SCR drives, it may be necessary to supply a more sophisticated SCR adjustable voltage system when the movable bridge is being driven by more than one motor. This is dependent solely on the bridge mechanical system.

SCR adjustable voltage control has been widely used on movable bridges for the last 20 years. Should this type control remain a movable bridge standard?

To address this issue, we must first examine what the future availability of this equipment will be. This type control is not being used to any large extent on other related drives. The crane industry has moved away from SCR primary voltage control to eddy current brake and other more sophisticated types of control. Other industries have switched to adjustable frequency type drives.

Many of the problems that are dealt with by SCR adjustable voltage with difficulty are handled more easily by other types of drive systems. These problems are:

1. Truly accurate position demands.
2. Multi-motor drive considerations.
3. Torque limiting problems.
4. The relative complexity of the control itself.

In conclusion, although still a viable movable bridge control system, the days may be numbered for SCR adjustable voltage control.

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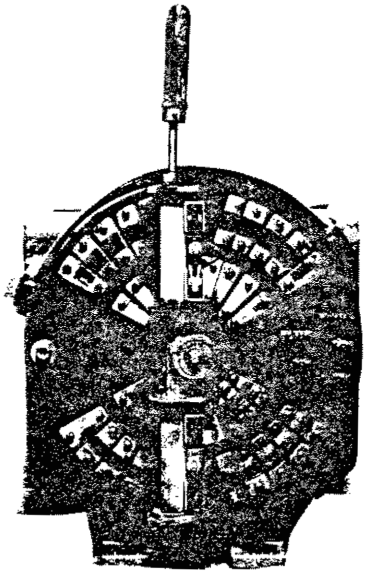


Figure 1 - Typical manual drum controller used on early bridge electrical systems.

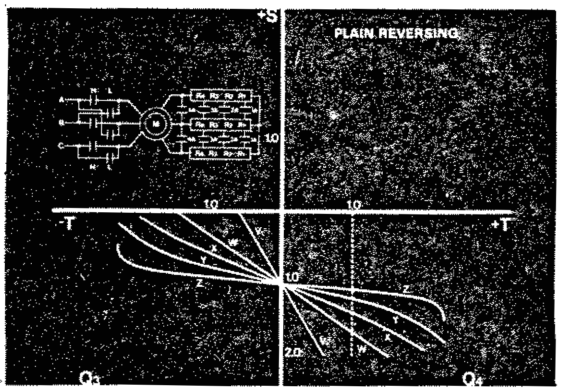


Figure 2 - Performance characteristics of manual drum or magnetic plain reversing controller.

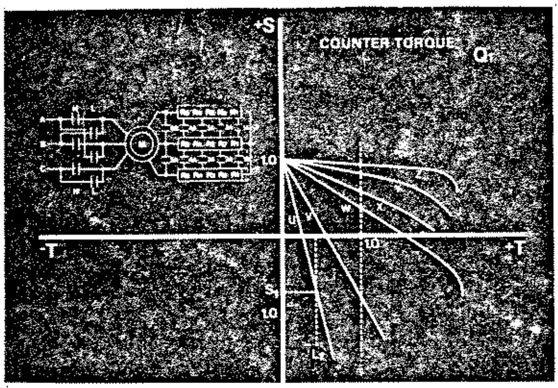


Figure 3 - Performance characteristics of magnetic counter torque controller.

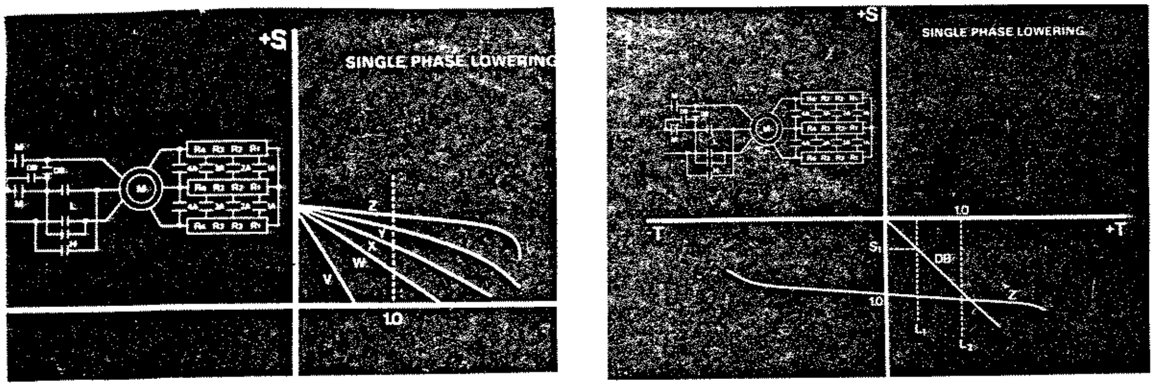


Figure 4 - Performance characteristics of ac dynamic lowering controller.

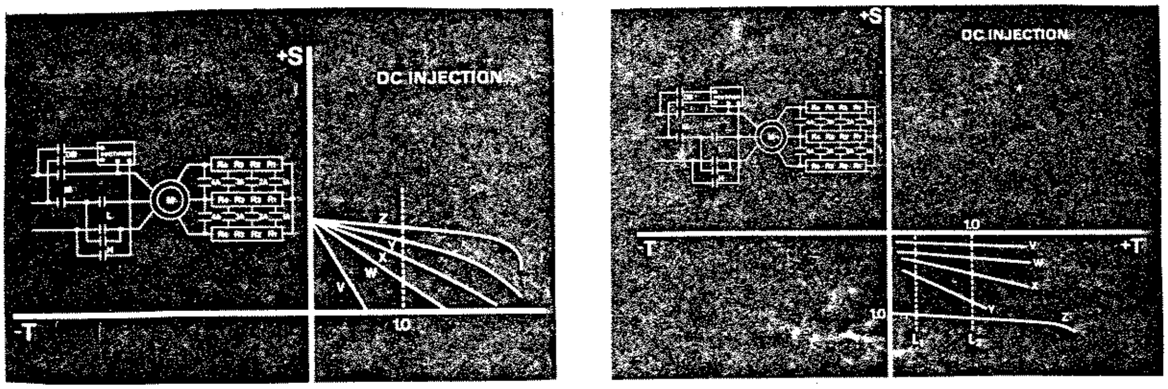


Figure 5 - Performance characteristics of dc injection type controller.

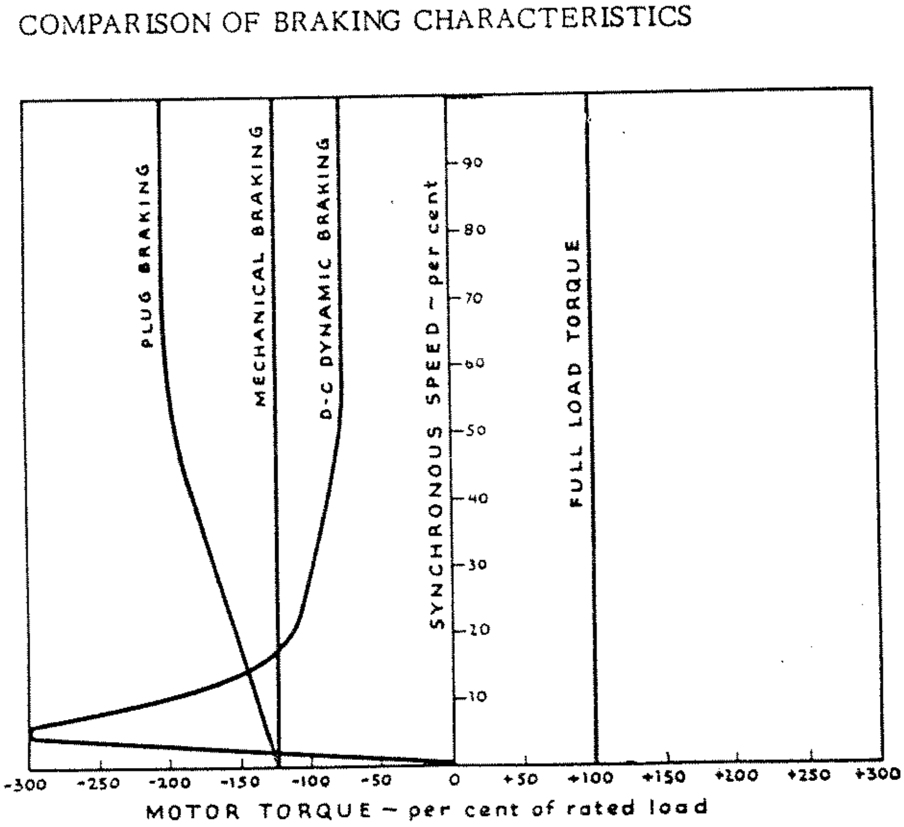


Figure 6 - Slowdown and braking characteristics of various methods (mechanical braking, plugging and dc injection).

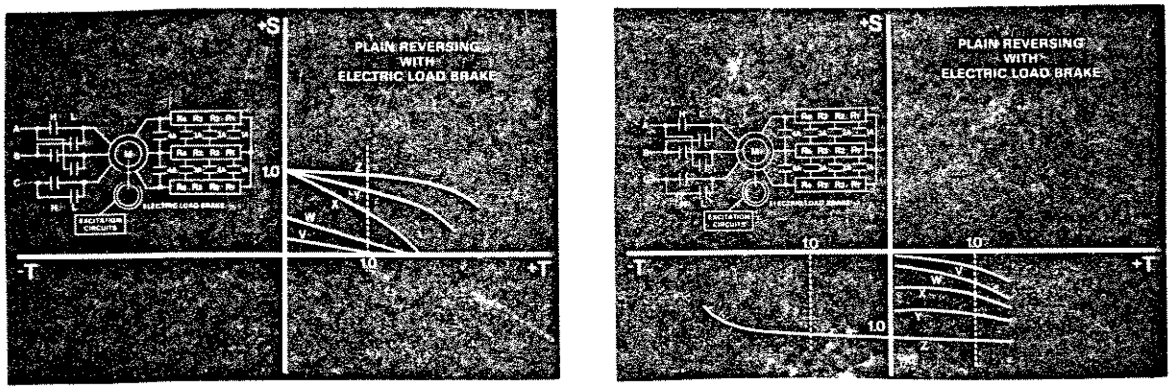


Figure 7 - Performance characteristics of eddy current brake and controller.

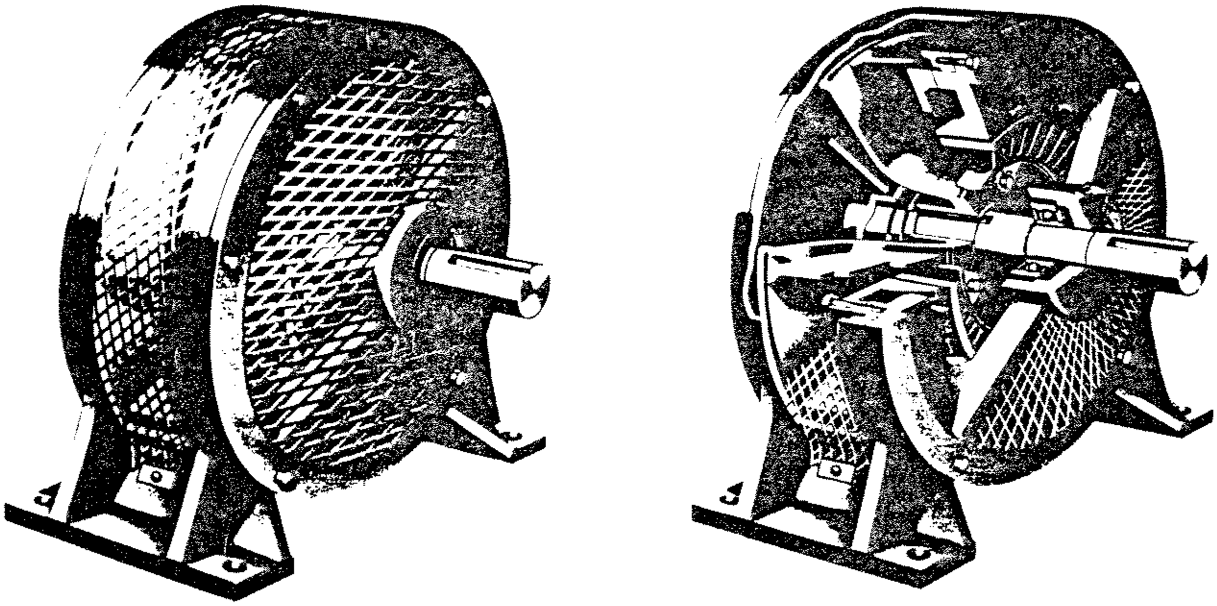
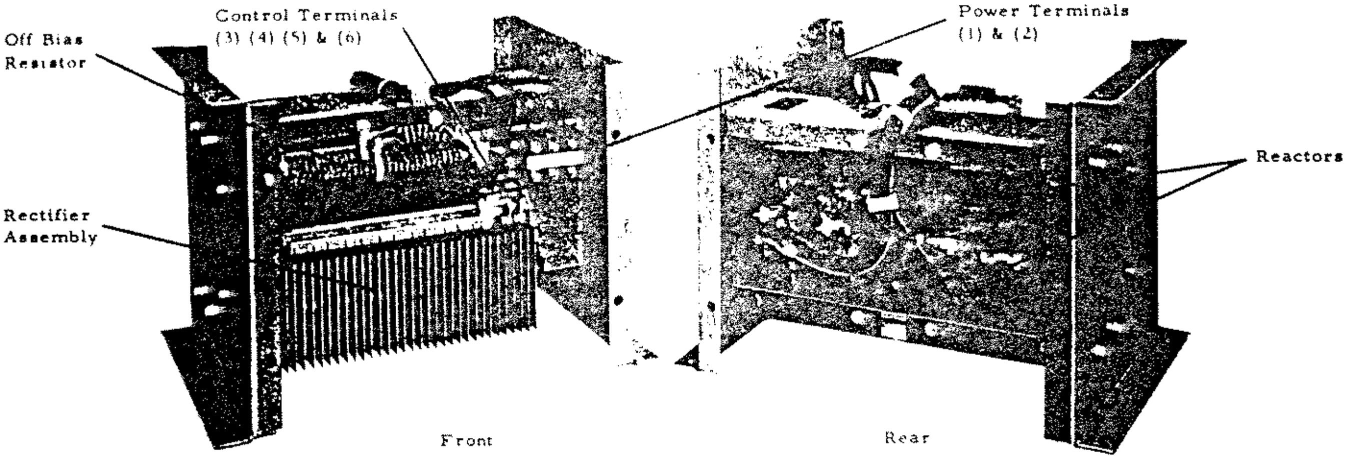


Figure 8 - Typical eddy current brake.



TYPICAL CORPAK POWER AMPLIFIER ASSEMBLY

Figure 9 - Reactor

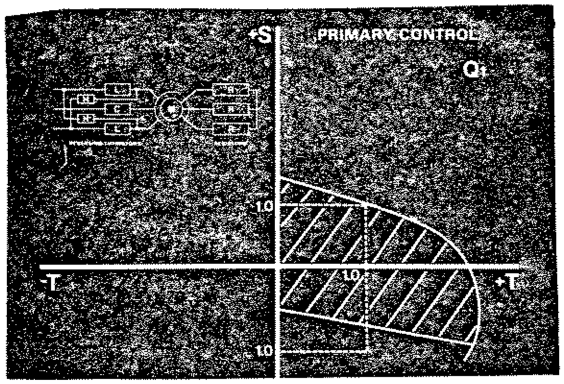


Figure 10 - Performance characteristics of solid state primary voltage control with overhauling and non-overhauling loads.

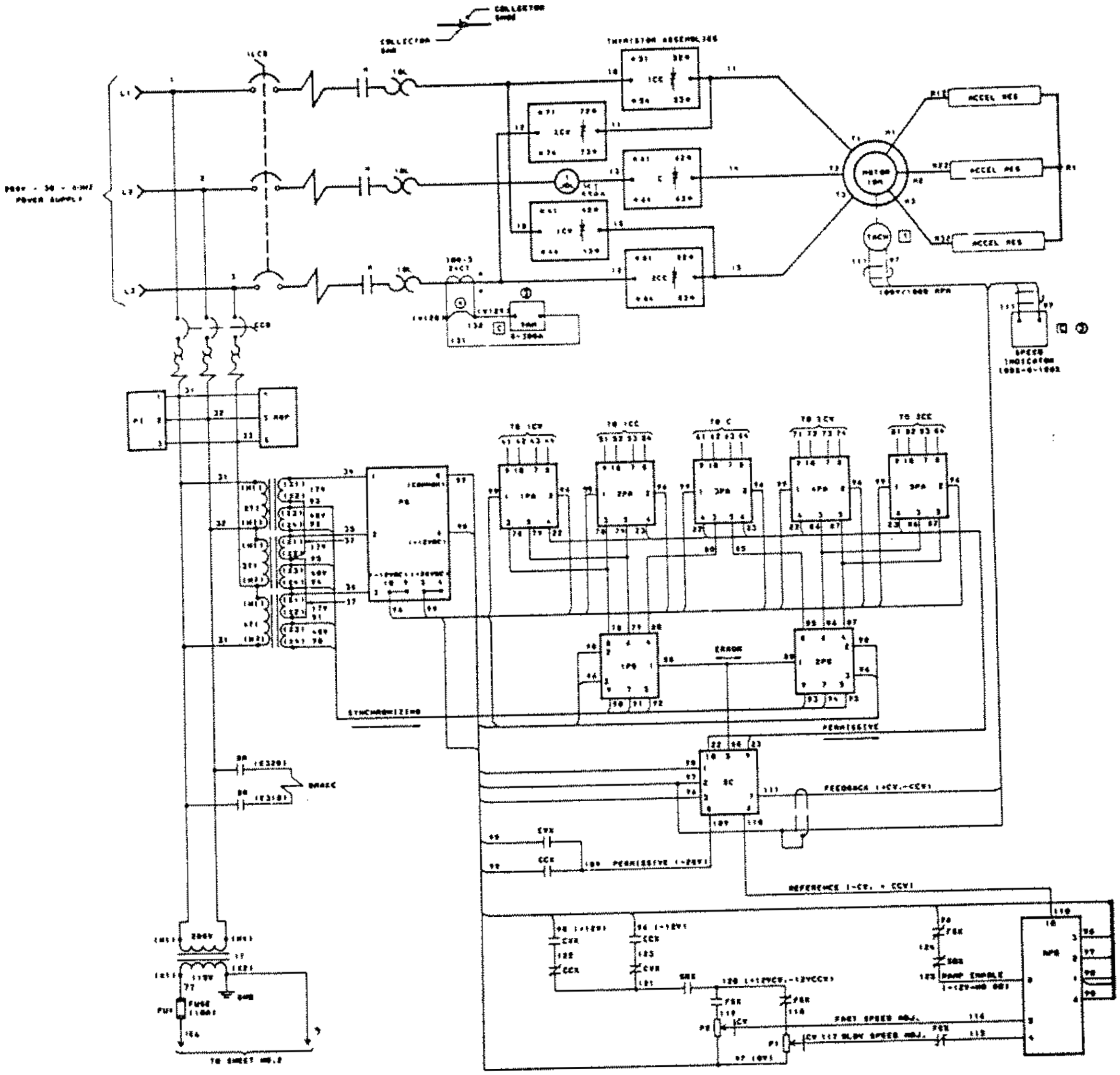


Figure 11 - Typical circuitry for solid state primary voltage control with ramp function generator.

Figure 12 - Typical movable bridge duty cycle.