Direct Current Bridge Drives

The First Biennial Symposium

on

Movable Bridge

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Presented By

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A Division of MagneTek, Inc.

Introduction

Bodies of water have proved to be a hinderance to the land travels of man since the beginning of time. Early man used logs to carry his possessions and then progressed to the rudimentary boat and on to makeshift ferries. As his modes of transportation became more sophisticated, bridges were built in order to allow him the luxury of using his cart and wagon for the entire journey. In his search for security, man devised the castle and its moat. Along with the moat came the drawbridge, the forefather to our modern day movable bridge.

In today's world, there are thousands of rivers and canals which are transversed with bridges which must move or open in some fashion in order to allow navigation by water vessels. Due to the modern engineering of 30 years ago, most of these bridges are still in service and it is doubtful that the structures themselves will "wear out" at any time in the near future. However, the mechanisms by which these structures are moved may have suffered at the hands of Mother Nature, Father Time, and human misuse to the point that they must be upgraded. New bridges are also necessary as the population increases and moves to new locations. New structures are therefore being designed utilizing the newest technology for both construction and control.

One prevalent method of control still in existence today is the wound rotor control. In many cases, it may have been instituted over 30 years ago. Another utilized DC motors powered from a constant potential DC bus. These systems generally require the coordinated effort of two operators, one on each side of the waterway. Each operator controls the raising and lowering of his respective span with a "streetcar" type drum switch which inserts series or armature resistors into the power input of the motor to control the speed. This requires a preponderance of skill and a little luck to get the leaves moving at the right speed, at the right time. In addition to the drum switch, each operator has a crank handle on his right to release the emergency shoe brake.

Alternate methods of control have recently been implemented to meet the demands of one-man operation, precise speed control under windy conditions, precise position control at closing, and capability of operation via telephone/computer and closed-circuit television from remote locations.

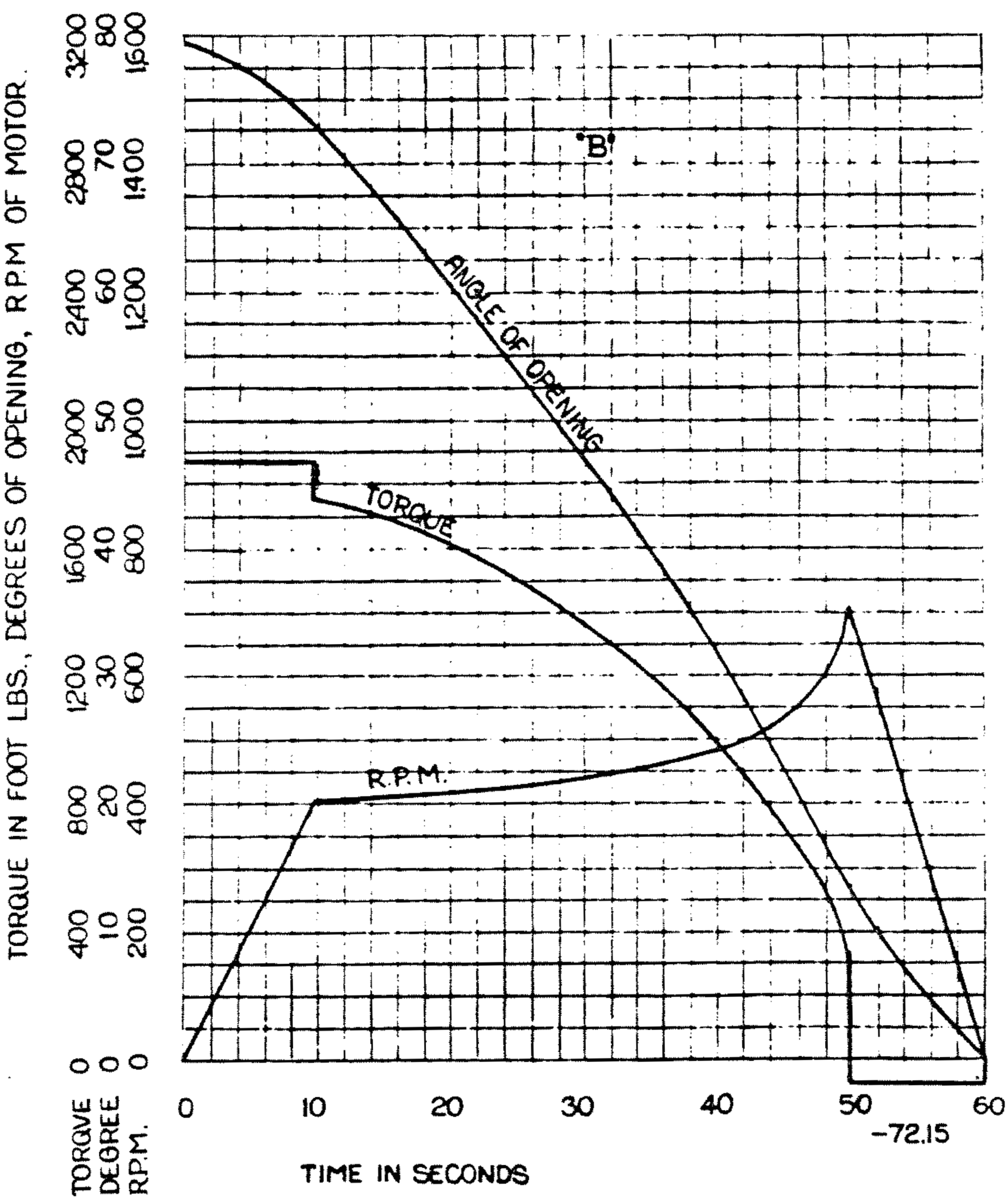
Desirable Characteristics of a Bridge Drive

Louis Allis has had previous experience applying variable-speed drives to numerous bridges at various locations throughout the United States, such as Wisconsin, Alabama, Illinois, and Florida. We're currently working on one for Ohio. Of course, while not all the requirements were exactly the same for these jobs, a number of desireable characteristics are apparent:

- Single control that is easily adapted for multimotor operation when there are two motors per leaf.
- Inherent load sharing when two motors are used.
- Capability of operating with just one motor during emergency conditions when two motors are normally used.
- Controlled acceleration and deceleration.
- Momentary overload capability during acceleration (see Figure #1 "Typical Speed/Torque Curve").
- Controlled braking or holdback capability during deceleration (see Figure #1).
- Easily reversible.
- Smooth and rapid torque control during transition from positive to negative torque in order to reduce the possibility of jarring the drive train or physically having the bridge "bounce".
- Speed control interface from various references, such as cam-operated limit switches, manual speed pots, hoist-type master switches, programmable controls, transducers, etc.
- Power efficiency.
- Controlled speed range.
- Maintenance and reliability.
- System that is well protected against fault conditions.
- Diagnostics and troubleshooting.
- Controller size and ease of installation. In some instances, there have been limitations due to existing space, door sizes and stairwells.
- Last, but not least, total cost.

Braking Methods

Before discussing various types of variable-speed controllers available, a number of definitions need to be reviewed.



LEAF OPERATING CYCLE FOR CLOSING AGAINST 10 # WIND

FIGURE 1

Plugging

The power leads to the motor are reconnected so that the output torque is reversed. This creates a "slamming" effect, both electrically and mechanically, to the motor. As a general rule, motors are not manufactured to withstand these abnormal forces unless the method of braking/stopping are so stated prior to being ordered. Therefore, special considerations must be taken in the design and manufacture of the motor. This must include consideration for excessive heating caused by the extremely high reverse currents introduced into the windings, i.e., higher class insulation, more steel in the rotor and stator, high efficiency cooling. Also, the windings must be secured with extra precaution to help alleviate excessive movement of the end turns at the moment of current reversal. This method cannot be used where countertorque is needed at standstill. As the speed nears zero, the power supply must be disconnected in order to avoid reversal of rotation.

Dynamic or Resistive Braking

In general terms, the motor is disconnected from the power source and means are provided to establish flux, which will cause emf's to be induced into the rotor. Discharge paths through resistive banks are arranged so that current flows, resulting in loss of energy and subsequent braking of the motor. No braking is available at standstill.

In using an AC motor, direct current is injected into the stator windings after it is disconnected from the power supply. This sets up a stationary field, inducing emf's and currents in the rotor circuit. This produces high braking torque, but the braking effect is less at high speeds and normal slip.

Regenerative Braking

It is an inherent property of most types of motors to operate as a generator when driven faster than no-load or synchronous speed. Of course, the power supply must have the ability to absorb the power that is generated. Braking torque increases with motor speed, providing ideal braking characteristics for motors that have overhauling loads.

With AC motors, the braking torque provided for a given slip is slightly greater than in the motoring mode and there is a speed where maximum torque is obtained. Dependent upon the control strategy used, beyond this value, the torque decreases as speed increases.

DC motors can be either shunt or compound-wound machines. DC machines will regenerate if either the field or armature voltages are reversed. This reduces the speed to the no-load value.

Regenerative braking is very forgiving in respect to the electrical and mechanical forces that may be seen by the motor. It is a very smooth and "easy" method of efficient braking. When properly controlled, the motor sees very little stress in the windings or the mechanical structure.

Reference Figure #2: (Assume "perfect" balance)

Quadrant I - Raising leaf, acceleration and running
Quadrant IV - Raising leaf, deceleration
Quadrant III - Lowering leaf, acceleration and running
Quadrant II - Lowering leaf, deceleration

Types of Variable Speed Drives

Now let's review some of the major types of controls currently on the market:

1. Automatic rotor control using wound-rotor motors.

2. Adjustable-frequency drives.

3. SCR control of direct current motors.

Automatic Rotor Control, Wound Rotor Motors

At the present time, this is probably the most widely used system for bridges today. Simplicity is its greatest virtue. It is rugged and can usually sustain limited operator abuse.

The wound-rotor motor performance characteristics are closely aligned to that of a single-speed, squirrel-cage induction motor. The significant difference is that the speed-torque characteristics of the wound-rotor motor are adjustable using different external resistance values. Starting torque is high with low starting current (desirable when limited power is available). (Figure 3). Once again, though, the wound-rotor motor is not easily adaptable to overhauling loads. There are no provisions for regeneration, only resistive braking or plugging. Of even greater importance in new structure design is the minimal speed regulation that can be obtained through the use of the wound-rotor control system.

Adjustable Frequency Drives

The two basic elements of an AFD are an ac/dc rectifier and an dc to ac inverter contained within the same enclosure.

4-Quadrant Speed Torque Operation

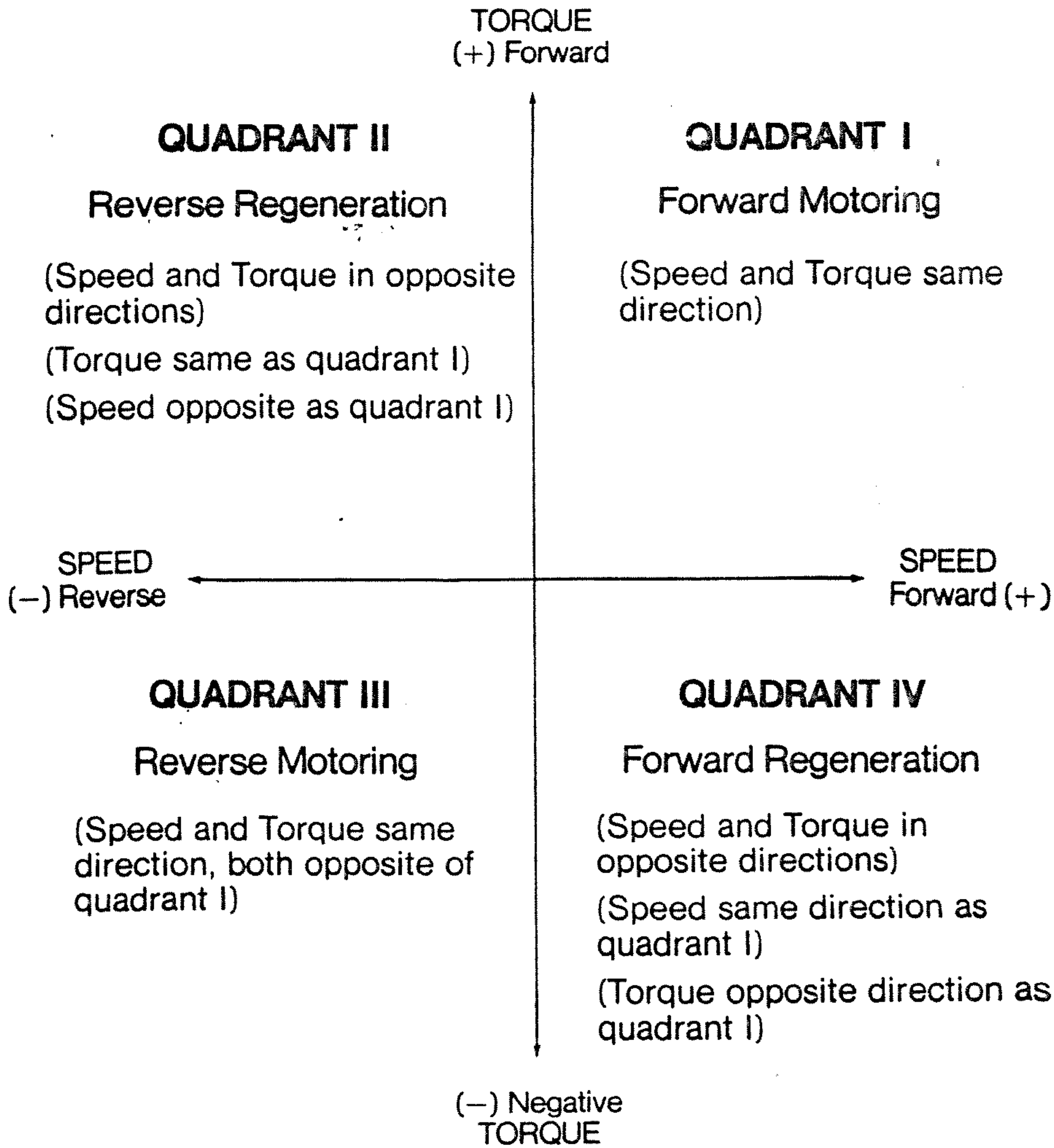
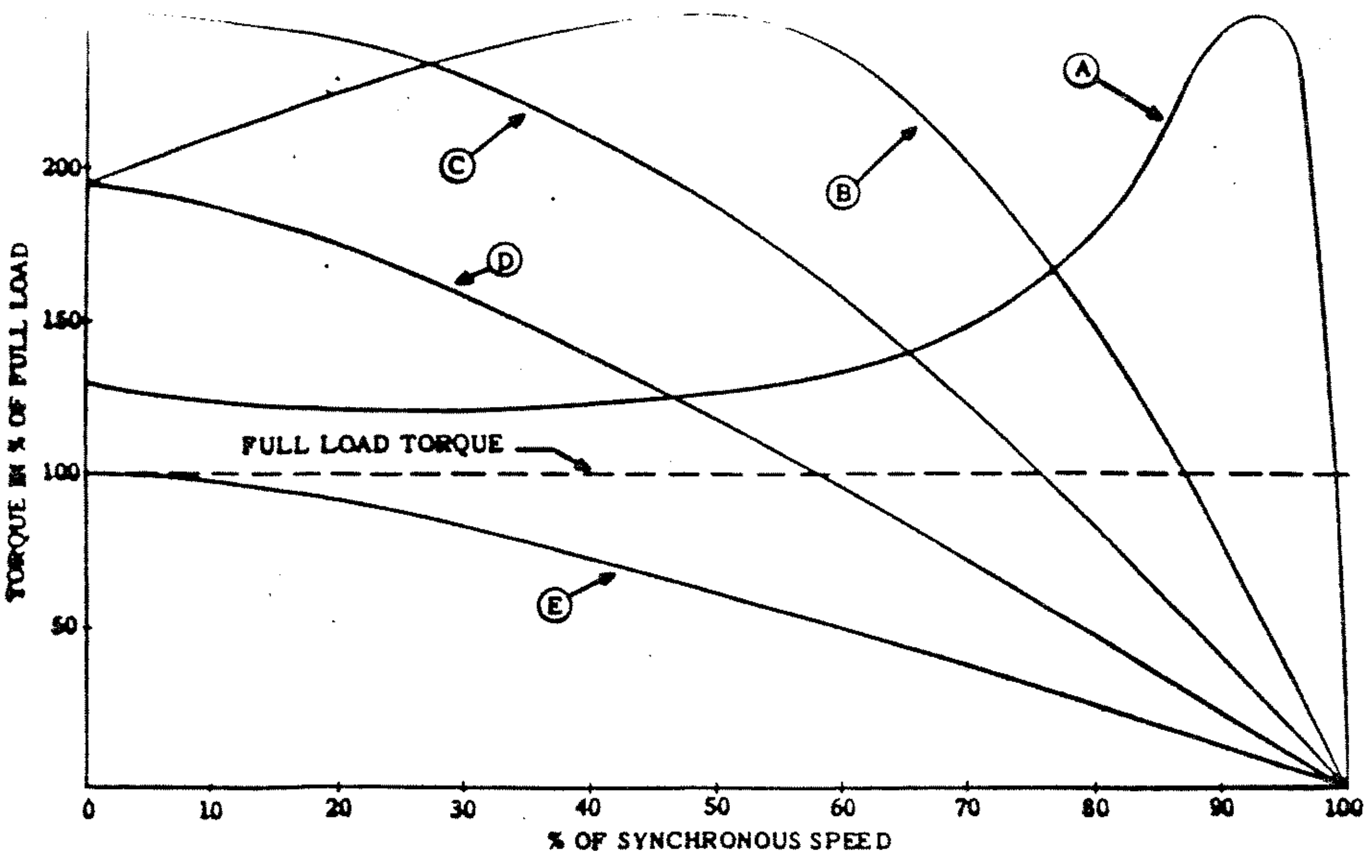


FIGURE 2



LEGEND:

CURVE	DESCRIPTION
A	ZERO EXTERNAL RESISTANCE
B	EXTERNAL RESISTANCE = 8–10% OF BASE RESISTANCE
C	EXTERNAL RESISTANCE = 15–20% OF BASE RESISTANCE
D	EXTERNAL RESISTANCE = 40–45% OF BASE RESISTANCE
E	BASE RESISTANCE (EXTERNAL RESISTANCE = 100% OF BASE RESISTANCE)

FIGURE 3

Incoming power is rectified into dc power, the dc is used as input to the inverter, which conditions the dc power and shapes it into a pseudo-sine wave of selected frequency. Heating of ac devices increases as frequency decreases; the surest way to kill an ac motor is to apply dc (zero frequency) to it. The reactance that is a function of frequency decreases as frequency is lowered, lowering impedance and causing more current to flow. To offset this principal, AFDs are designed to maintain a constant volts/Hz ratio at all frequencies from zero to base speed (60 Hz). This constant volts/Hz relationship automatically compensates for the reduction in reactance as frequency is varied, and preserves constant torque.

Although the basic elements of an AFD (rectifier and inverter) imply overall simplicity, the inverter is, in fact, a complex item of electronic equipment. The complexity also varies with the particular principals used to achieve a good approximation of a sine wave. Although recent advances in technology have promoted many variations of controllers presently on the market, for the most part, they can be broadly categorized as being either current-source type or voltage-source type.

Current Source Inverters

Current-source inverters (CSI) generally employ SCR rectifiers, a high impedance link, and SCR inverter sections. Some designs do offer diode bridge rectifiers but on a limited basis. The high impedance choke between the rectifier and inverter gives extremely good current protection allowing the system to withstand many external and internal faults without damaging the components themselves. It generally has the least complex circuitry of the AC drives making it easier to maintain. The current waveform is well defined and the voltage waveform is sinusoidal (Figure 4). Since the drive is current regulated, torque is regulated. The drive is also inherently regenerative in nature. This fact, coupled with the current/torque regulation, allows the user to have an extremely accurate drive which will react to minute load changes almost instantaneously.

Voltage Source Converters

The voltage-source AC drive is the most common type of drive in use today. As stated earlier, it merely changes line voltage and frequency to a settable voltage and frequency but allows the motor to respond within its speed/torque parameter. Current is not regulated, but rather limited to a preset value. A Square 6 Step inverter produces a square 6 step voltage; however, the current waveform seen by the motor is full of random excursions as produced by the load demand (Figure 5). Since the VSI is a

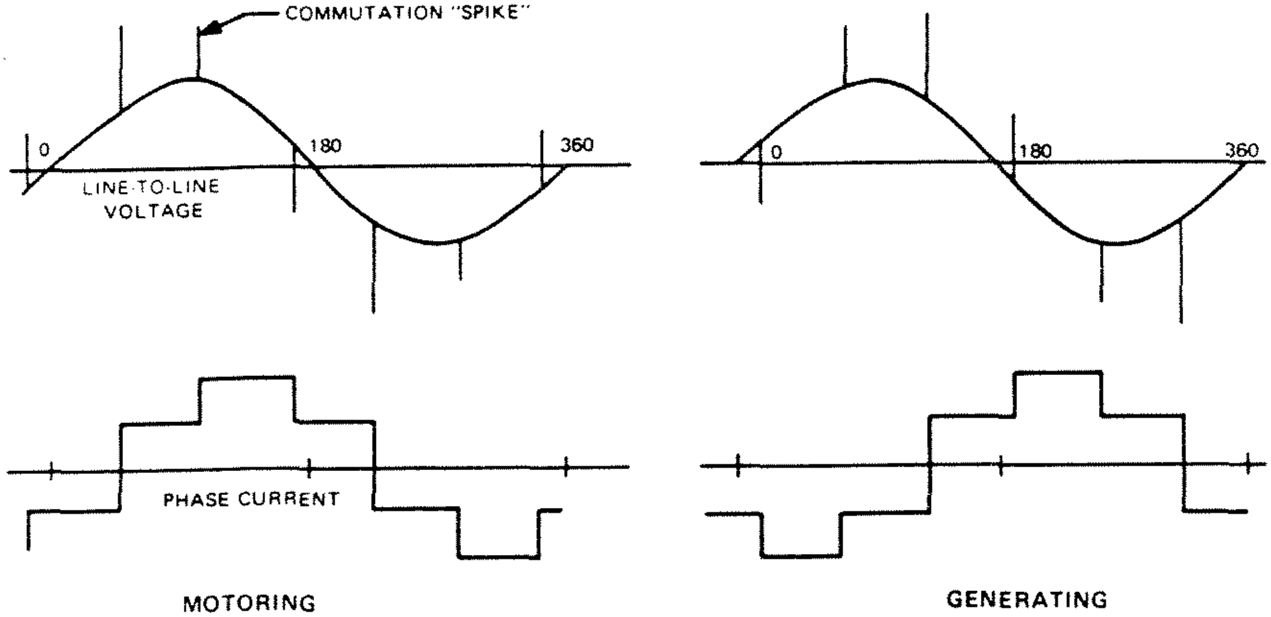


FIGURE 4

low impedance device utilizing a large capacitor choke in the link between rectifier and inverter, it has the distinct capability of self-destruction by the large amounts of current stored in that capacitor.

The Pulse Width Modulated drive is another form of VSI. The waveform of voltage "looks" almost sinusoidal to the motor. In reality it is made up of many smaller pulses regulated by the frequency control of the system (Figure 6). The PWM inverter is generally not sensitive to motor characteristics except that it must avoid low per-unit reactance.

VSIs are a very good drive for multimotor systems as long as extreme care is taken in selecting and sizing the motors properly. It is also easy to add resistive braking, but very difficult to add regeneration.

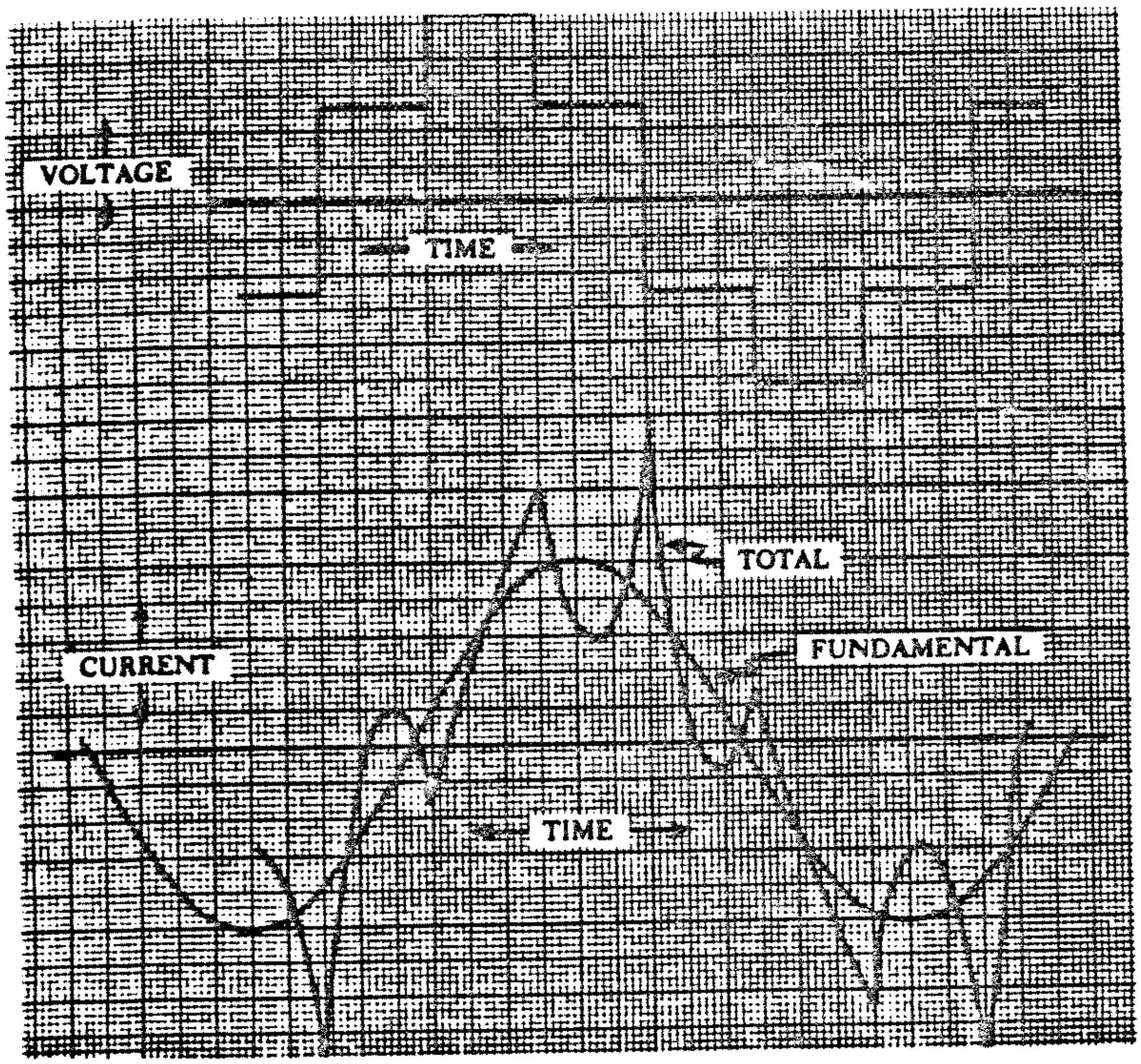


FIGURE 5

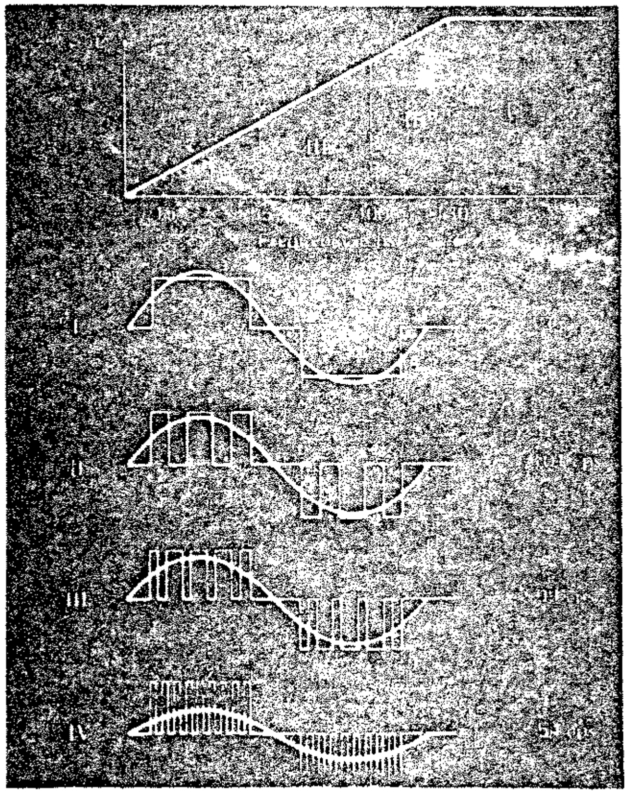


FIGURE 6

Direct Current SCR Control

The DC drive has long been a mainstay of industry throughout the world because the characteristics of a DC motor make it inherently variable speed. For a stabilized shunt motor, speed is proportional to armature volts, and torque is proportional to armature amps. Virtually every manufacturing process known in modern industry has been driven by the DC drive. These applications include pumps, conveyors, extruders, wire and cable stranders, paper machines, coaters, laminators, crushers, chippers, cranes and hoists, and on and on. The electronic control itself is fairly simple to understand and maintain. The DC motor is extremely rugged and reliable with well-defined speed/torque/horsepower parameters.

The DC drive that is to be utilized is a multiphase four-quadrant phase-controlled rectifier. Its primary intention is for the control of the direct current motor armature, particularly where current must be well-controlled over a wide operating range, including near zero, or where rapid current reversals are required. The special criteria, of fast response and smooth current (torque) reversal, make this converter noticeably different from other equipment currently in use.

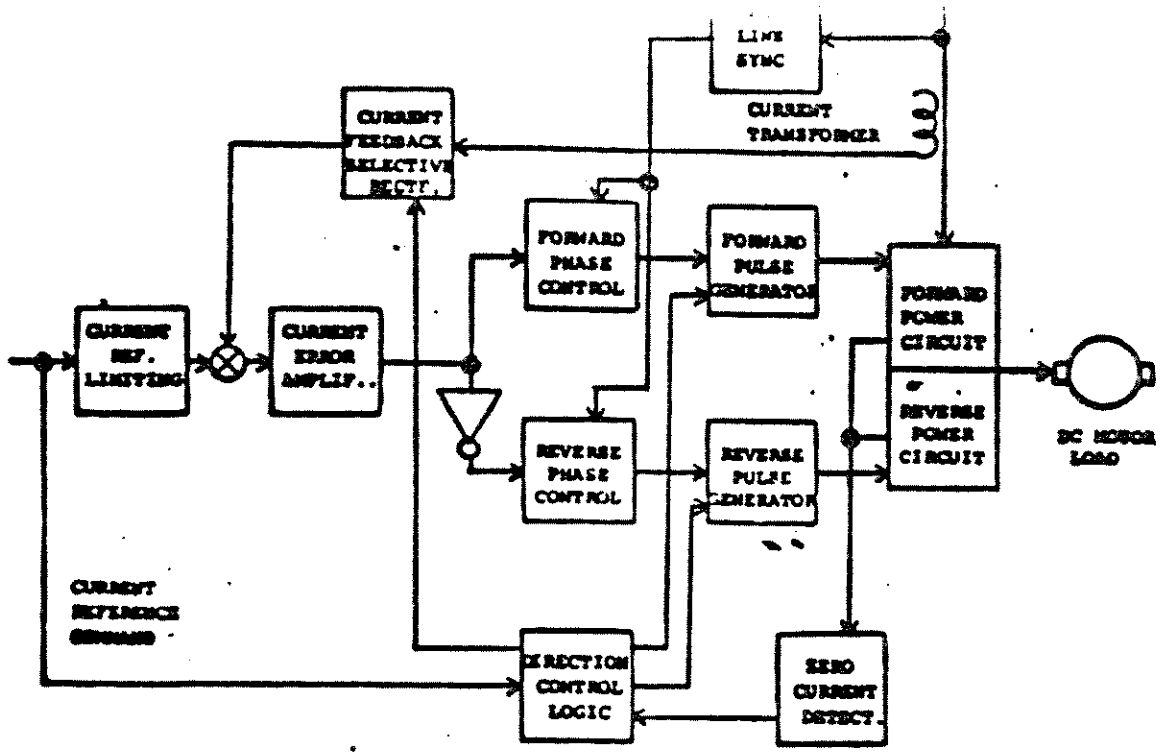
The bridge drive must have variable capabilities. It must be capable of supplying small amounts of torque in either the motoring or regenerating modes. It must also be capable of supplying maximum amounts of torque to accelerate or decelerate the equipment under normal and adverse conditions. In this instance, the regenerative motor controller must be able to adjust from motoring demands to regenerating quickly and smoothly without any discontinuity that may cause disturbances in either the regulating circuitry or torque pulsations or ripples as applied to the driven machinery. The smoothness of operation of this drive system prolongs the life of the mechanical components of the bridge itself.

This drive must also be able to respond extremely quick. It should be able to respond with smooth characteristics near zero operating current, including current reversal. The four-quadrant controller should be able to perform at speeds limited only by the load inductance. When a current reversal is required, no time can be wasted pondering whether or not it is safe to switch current control from one set of thyristors to the other. This decision must be made accurately so that line-to-line faults do not occur through the thyristors and quickly so that no significant delays are introduced that may disturb outer control loops. For smooth operation near zero current, special considerations must be taken to ensure that there is a continuum of control from the command signal input to current flow in the power output, regardless of discontinuous conduction or motor CEMF. No deadbands can be allowed since it would hinder smooth operation and surely degrade the time response.

The basic block diagram of the four-quadrant DC drive is seen in Figure 7. This system has been discussed in great detail in every text available on the subject. Suffice it to say, this is an extremely accurate method of control that has proven itself for many years. Figure 8 illustrates bidirectional flow of current that would be present within the motor during periods of either motoring or regeneration.

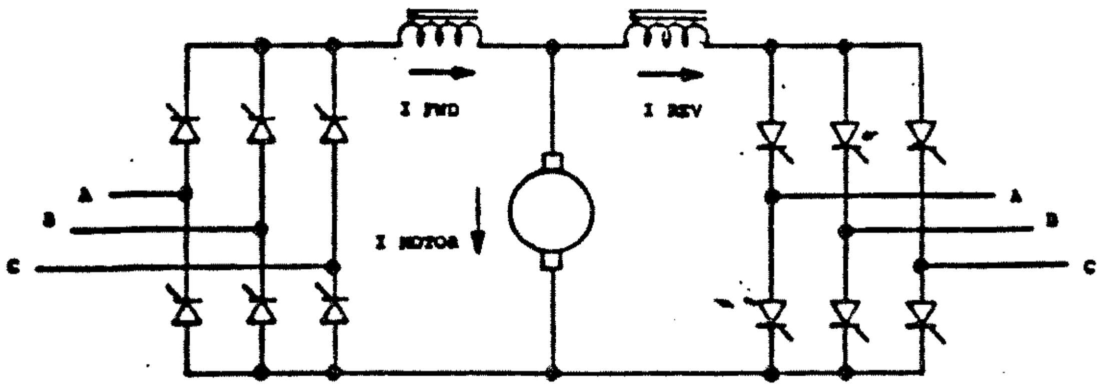
Comparison of AC and DC Drives

Louis Allis has been manufacturing both AC and DC drives since before 1950 and was one of the first to develop and manufacture the adjustable-frequency type control. Louis Allis has the capability to provide either, but all of the previously mentioned



FOUR QUADRANT RECTIFIER CONTROLLER BLOCK DIAGRAM

FIGURE 7



I MOTOR = I FWD - I REV.

BI-DIRECTIONAL MOTOR CURRENT FLOW WITH CIRCULATING CURRENT BETWEEN POWER CONVERTERS

FIGURE 8

jobs entailed using static DC four-quadrant regenerative drives. The reason for this may become apparent when the aforementioned desireable characterics that are merited by the application are reviewed. Reference Figure 9. Some of the characteristics involved with the DC drive will be explained later in further detail.

Practical Application of DC Bridge Drives

Emphasis has been placed on several terms throughout this paper. Proper treatment of these terms as to how they relate to a moveable bridge drive system shall be incorporated into the following text.

Why the emphasis on regeneration and regenerative drives? Referring back to the definition of regenerative braking, this is an inherent property of all motors. It is there, so why not use it? Plugging is definitely not a natural characteristic. Imagine yourself in an automobile, traveling at 55mph, and an outside command says "Put the transmission in reverse. . .NOW!! I think you can imagine the resultant forces applied to the transmission, differential, axle, and yourself. This is basically what happens to the motor in a plugging condition. The resultant current reversal produces very high current in the windings which, in turn, produce very high temperatures that can deteriorate the insulation at an advanced rate. The mechanical forces are felt not only in the motor, but also in the mechanical devices to which it is coupled. This can result in premature failures of motor shafts, couplings, and gears. Torque is not available as the motor speed

Characteristic	Regenerative DC (Saber 3412)	Variable Frequency (Lancer) Current Source	Variable Frequency (Lancer) Voltage Source
1. Multimotor	- Easily accomplished. - Any #/size combination may be accommodated.	- Not easily accomplished. - #/size combination severly limited.	- Easily accomplished. - Any #/size combination may be accommodated.
2. Load sharing between motors.	- Armatures connected in series. - Calibration resistors used to match speed and load.	- Multimotor severely limited (see above).	- Motors connected in parallel. - Adjustment of load distribution very difficult.
3. Controlled accel/decel	- LAC and decel adjustable from 1-40 seconds. - Adjustable current limit from 10-200%.	- LAC and decel and CL adjustable (various ranges)	- LAC and decel and CL adjustable (various ranges).
4. Overload Capability	- Controls are rated 150% for 1 minute, 200% for 10 seconds. - Stndard industrial motors are rated for 260% or more, for short periods.	- Usually 150%/min. (converter limitation)	- Usually 150% 1 min. (converter limitation)
5. Controlled Braking	- Fully regenerative. - Controlled stop, pre-engineered and plug-in.	- Full regeneration with no additional power hardware. C.S. easily available.	- Full regeneration available with additional power hardware. C.S. easily available.
6. Reversing	- Inherently reversible. - Both forward and reverse current limit.	- Readily available.	- Available.
7. Smooth Torque Transition	- Zero dead-band.	- Zero dead band very simple to provide.	- Zero dead band very difficult to provide.

Characteristic	Regenerative DC (Saber 3412)	Variable Frequency (Lancer) Current Source	Variable Frequency (Lancer) Voltage Source
8. Speed Control	- 5% speed regulation via armature voltage feedback. Improvement possible when motor mounted tach is used. - Plug-in, pre-engineered follower options. Either isolated or nonisolated available. - Preset speed, activated by external contact signals. - Fully adaptable to remote operation.	- Inherent 2 or 3% speed regulation due to ind. motor characteristics. - 0.5% readily available w/o tach, 0.1% w/tach. - Followers, preset speed, same as DC.	- Inherent 2 or 3% speed regulation due to ind. motor characteristics. - 0.5% readily available w/o tach. - Followers, preset speeds, etc., same as DC.
8. Efficiency	- Slightly more efficient in general (no inverter component required). Some small transistorized AC drives are comparatively more efficient.	- Slightly less efficiency than static DC. Transistor types more efficient.	- Slightly less efficient than static DC. Transistor types more efficient.
9. Controlled Speed Range	- 20:1 by armature control. - Wider with addition of tach.	- 5:1 easily attainable.	- 20:1 by armature control. - Wider with addition of motor-mounted tachometer. - Motor must be properly sized or use blowers for cooling.
10. Maintenance & Reliability	- Relatively simple control. - Both brushes and commutator must be properly maintained. - Spare DC motor more difficult to obtain than AC. - Modular construction.	- Relatively complex control. - No COMM or brushes. - Motor readily repaired or spared.	- Relatively complex control. - No CONN or brushes. - Motor readily repaired or spared.

Characteristic	Regenerative DC (Saber 3412)	Variable Frequency (Lancer) Current Source	Variable Frequency (Lancer) Voltage Source
11. Fault Protection	- IST - Low voltage protection. - Single phase pro. - Phase insensitivity. - Motor & control overtemperature. - Transient protection (MOVs & RC snubbers) - Current limiting fuses.	- Same as DC. - Same as DC except MOVs not always used.	- Same as DC. - Same as DC, except MOVs not always used.
12. Diagnostics & Trouble-shooting	- Optional digital test meter. - Fault indicator to monitor first of a series of possible faults.	- Same as DC.	- Same as DC.
13. Controller Size	- Relatively small.	- Much larger than DC.	- Larger than DC
14. One Motor Capability (2-Motor System)	- Motors must be adequately sized and provided with appropriate disconnects.	- Very difficult.	- Not difficult.
15. Total Cost	- Horsepower related. - Generally less than AC.	- HP related. - Greater than DC.	- HP related. - Greater than DC except in small sizes.

FIGURE 9

nears zero. Dynamic braking is much easier on the motor and associated equipment, but with this method, there is no control over motor speed or torque. With the DC regenerative system, braking is quick and you maintain control over the motor braking torque.

Movable bridges are generally counterweighted to allow movement with much less torque and horsepower than if they were just dead weight. Theoretically, they should be balanced so that minimum force is required to either raise or lower the span(s). In the real world, most bridges are not balanced correctly, especially the older structures. As time passes on, surfaces can be resurfaced and this adds more weight to the span making the system span heavy. Deterioration of metal counterweights can reduce the balancing effect. Changes in friction coefficients of gears and other related surfaces also play a part in unbalancing the system. As all these factors come into play over the years, the bridge becomes an unknown force to deal with, unless extensive testing is done to determine the exact weighing of both the span and counterweight. Therefore, as a span is either raised or lowered, the fulcrum point of the system changes. This means that the control system can see either a motoring demand or a regenerating demand at any point throughout the traverse of the span. Therefore, the drive system must be capable of enduring either motoring and regeneration modes at any point of the span travel and it must be capable of determining this mode of operation instantaneously without loss of control.

In northern climates, ice loading can cause the same problems in changing the balance of a system. Ice loading is a constantly changing parameter. Thickness and weight of ice can change thousands of times during a 24-hour period of time. Location of the ice can also shift, placing more weight on the nose of the span or the pivot point of the span as the day progresses. What may have been a sometimes motoring - sometimes overhauling load can become solely one or the other throughout the entire span of travel.

Wind loading is not restricted to any particular climate. Wind can change the type of load at any time, depending on speed, direction, and location of the span in its travel. Just as with ice loading, wind can produce shifting motoring or overhauling loads to the drive system.

With all the changing forces acting upon a bridge, the DC four-quadrant regenerative drive provides the most accurate control of the motoring-overhauling demands as seen in real life operation. The zero deadband of the drive and the accurate speed control provide very smooth operation, even though the bridge may shift from motoring to overhauling almost at will.

Since the true regenerative drive is pumping power back into the power source, the end user is also saving money as compared to the power consumption of other systems. When using either wound rotor or dynamic braking methods, the regenerative power is being dissipated into resistor banks or radiated into the atmosphere via the motor housing. With the four-quadrant drive, the previously wasted power can now be used to reduce the overall power consumption of the bridge installation. If you consider that the Clark Street bridge in Chicago is being raised and lowered around 7,000 times per year, and that probably half of the time the system is in the regenerative mode, the energy savings can be quite substantial. This aspect should not be forgotten, especially as power costs continue to increase every year.

The subject of "smoothness of operation" has been mentioned quite a few times. I am sure that you may wonder why there has been so much emphasis on this topic. Due to the mechanical design of a movable bridge, its inherent characteristics would appear to preclude a smooth operation. In other words, it is not a precision instrument. The initial starting of movement of the standard bridge imparts heavy stress on the bridge structure. If this initial movement is a forceful jolt, then it is logical that it will suffer detrimental effects over a given period of time. The DC drive has the ability to start the entire sequence into motion with a controlled amount of force. With the use of linear acceleration rates, the span can be gradually brought up to speed. There is also the availability of utilizing an S curve type of acceleration which provides an even softer start before proceeding into the acceleration ramp of the drive. Torsional stress on drive shafts, surface friction on the face of gears, and angular forces on the foundations that hold everything together are greatly reduced.

With the use of controlled acceleration, the span can be brought up to any preset speed. At that point, the span will travel at said speed until it reaches some predesignated point in the span travel. At this point, the need for stopping the span in a controlled manner arises. Now the linear deceleration circuit will take control and bring the span toward standstill at a controlled rate. Once again, the span is controlled without imparting unnecessary strain on the structure itself. Generally, the span is brought to certain point and the motor brake circuitry is activated. As the span engages various devices, such as limit switches, it is brought to a relatively smooth stop, even if the load is overhauling at the time. This can be appreciated as you sit in your automobile and watch the operators of an old style bridge bounce and dribble the span to a stop, the live load area fractures, and the nose interlock is sheared off because he engaged it too soon. At this point in time, the drive should have the capability to position the span and control its speed. After coming to a complete stop, the drive needs the little added push to position the nose to ensure proper engagement of the interlock without having to guess if the nose is in the correct position. This is sometimes called "creep" speed control and easily obtained with the DC drive system.

Each and every designer devises his own sequence of control for the raising and lowering of a bridge. Various prescriptions for speed control, position control, controlled stopping, and emergency stopping are issued forth by the individual specifications. The one control that is easily adaptable to virtually any method of command is the DC control. The simplicity of the circuitry makes it readily accessible by relay logic, programmable controllers, telephony, or even manual control. Remote control from off-site operators is easily obtainable.

Circuitry design of the Louis Allis Saber 3412 DC drive enhances the reliability of a bridge drive system. Due to the less than desirable location of most bridges, the power source is subject to random disturbances. This, in turn, creates spikes and/or notches on the incoming power line. Louis Allis has incorporated line snubbers and reactors to lessen the effects of these disturbances. Should a line notch proceed past the incoming protection, the Saber 3412 incorporates an SCR gating system known as "Posi-Gate". The conduction of an SCR is monitored and if, for any reason, this conduction stops prematurely due to line notches, the Posi-Gate firing circuit will refire the SCR for the correct period of time. This assures that power to the motor is not interrupted at any time, once again, insuring smoothness of operation.

All major power sections of the Saber 3412 are modularized for quick and easy replacement, should the need arise. Printed circuit boards are of the quick disconnect type. With the addition of a test module, any operator should be able to determine 90% of the failures that may occur and affect a quick repair of the system. Factory testing of both components and systems is standard procedure for Louis Allis.

In the following Appendix are one-line diagram examples of a number of existing Louis Allis bridge drive installations.

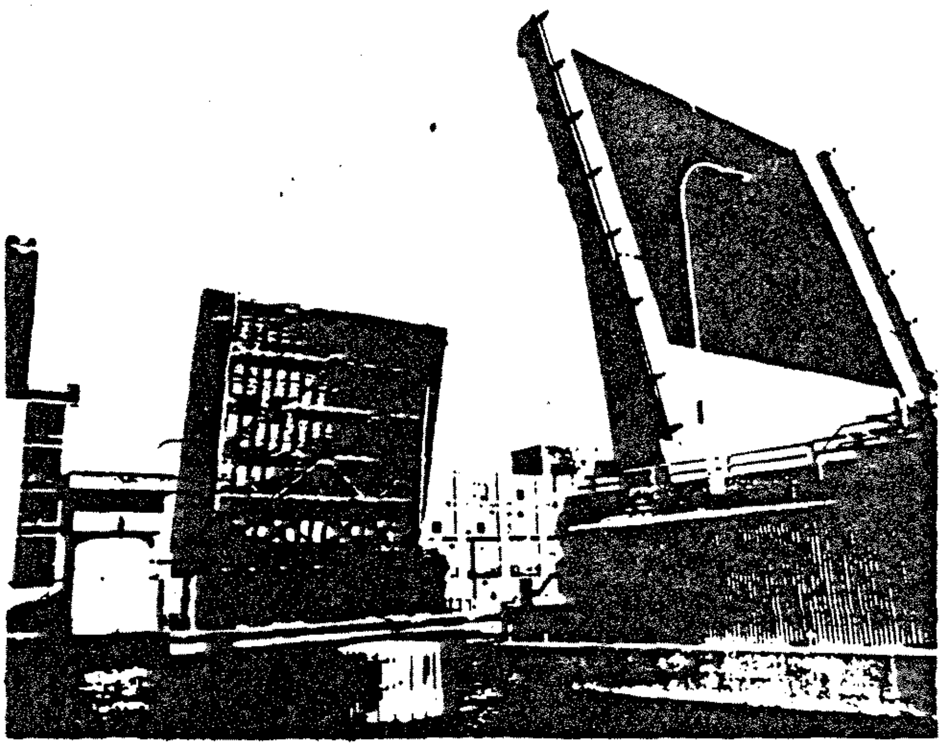
APPENDIX

CURRENTS FROM LOUIS ALLIS

Litton

VOL. III, NO. 6 | Published for Internal Use Only | NOV. / DEC., 1982

NEW 1000-TON BASCULE BRIDGE OVER MILWAUKEE RIVER POWERED BY LOUIS ALLIS



A new bascule bridge, the first to use a static DC regenerative drive system, recently opened in Milwaukee. Electric motors and controls for the Broadway Bridge, owned and operated by the Milwaukee Department of Buildings and Bridges, were provided by Louis Allis.

"Three factors were important to the Department in deciding to choose Louis Allis' drive system" said Carl Schroeder of the Milwaukee District Sales Office. "The first requirement was that the bridge be operable by one person". Two operators were usually needed to raise and lower older bascule bridges – one for each half.

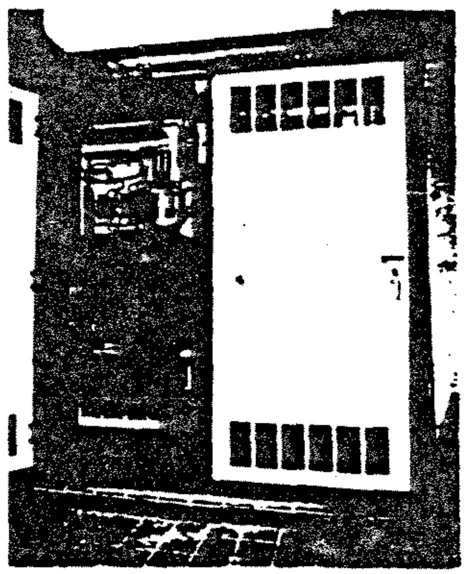
In a typical year, it is estimated that the 365 ft. long 1000-ton Broadway Bridge, which spans the busy Milwaukee River, will be raised and lowered approximately 7,000 times.

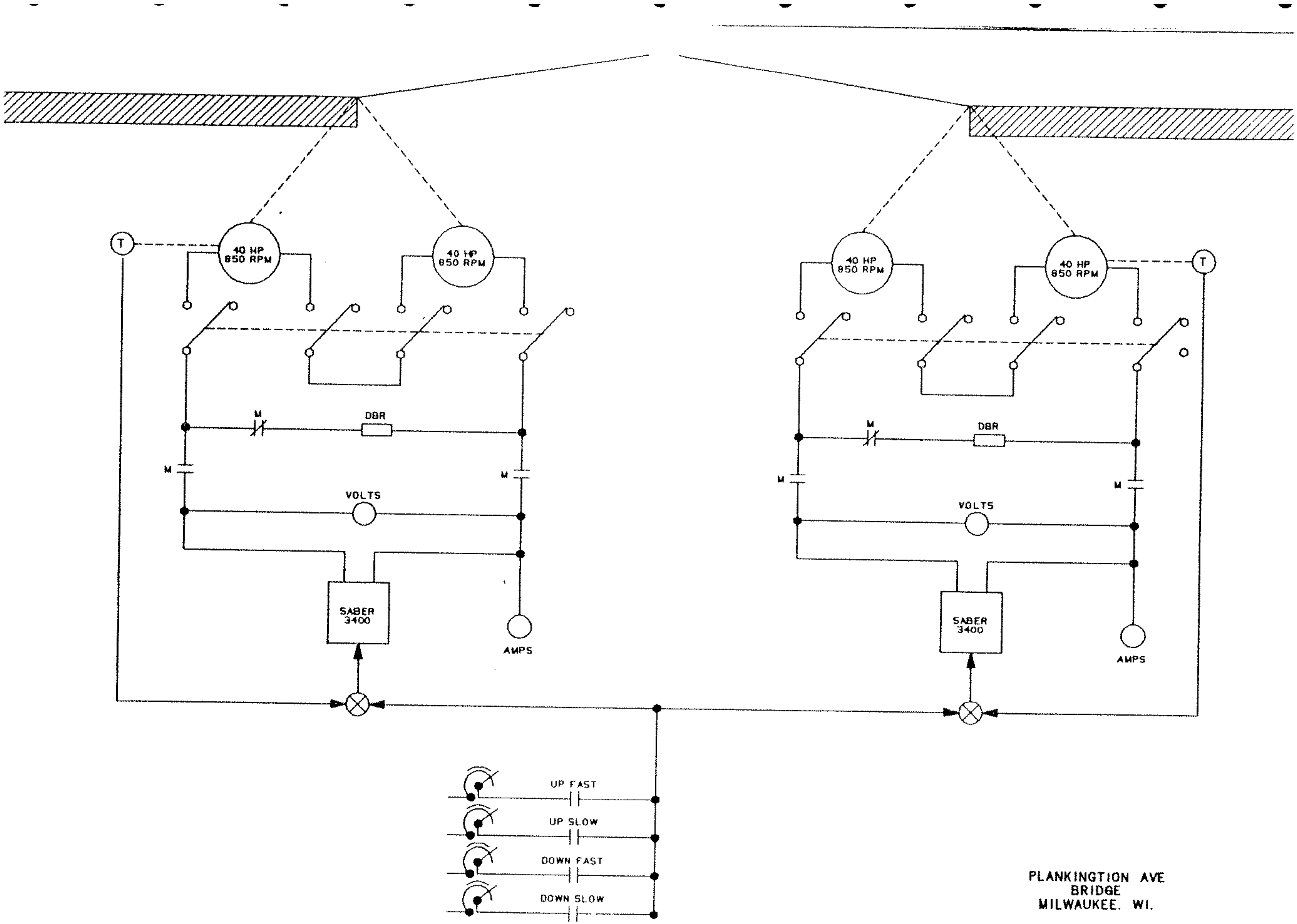
The Department's second requirement was that the system be able to provide strong and accurate bridge control under harsh environmental conditions.

Third, the drive system also had to be capable of conversion to remote control by telephone and closed circuit television to provide 24-hour use of the bridge.

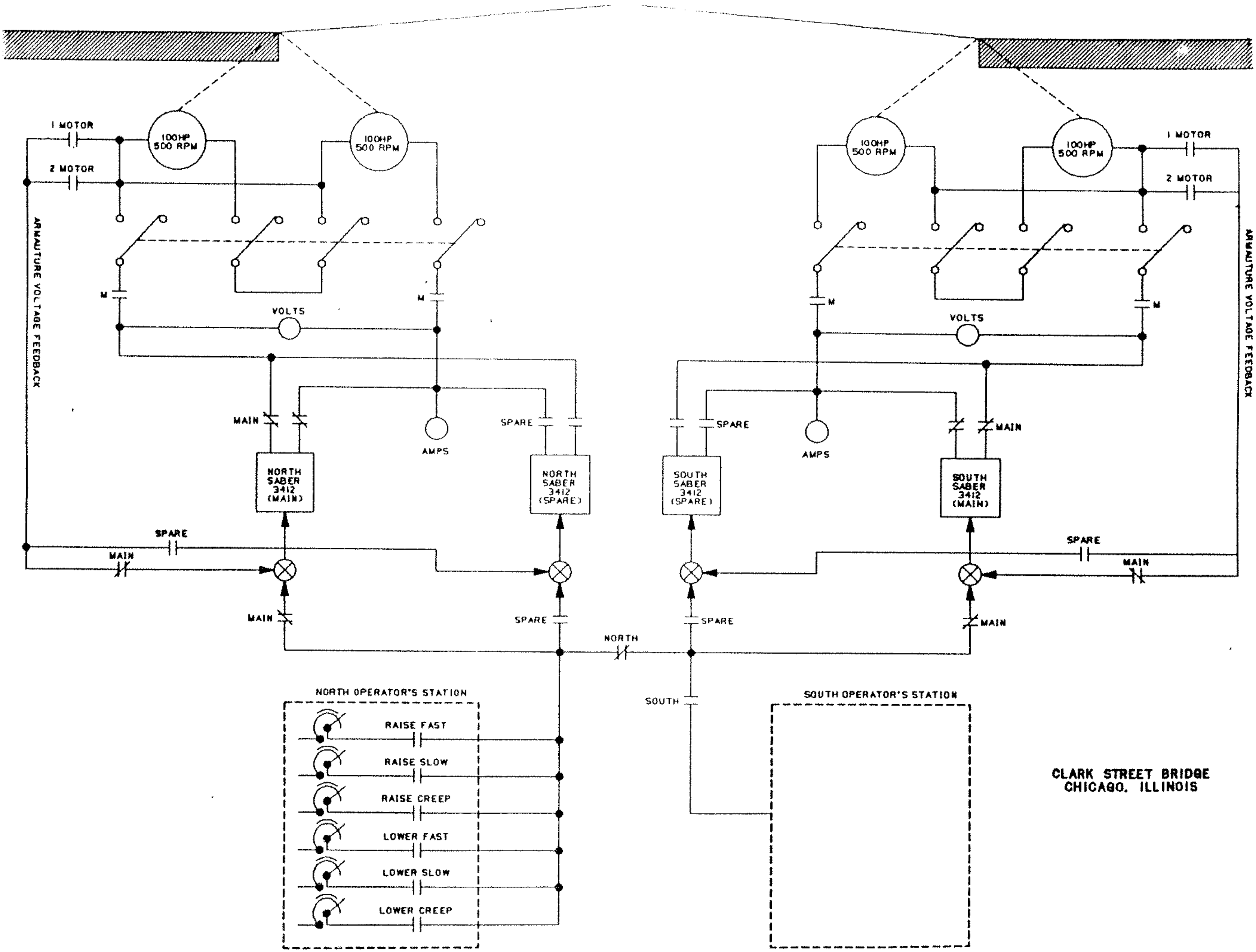
The "brains" of the system provided by Louis Allis are a pair of 100 HP Saber 3400 DC regenerative power supplies, one for each leaf, or half, of the bridge. This is the first use of a static DC regenerative drive system on a new bridge, although two other existing Milwaukee bridges were converted to Louis Allis static DC regenerative drives in 1980, and have been operating smoothly since installation. Each Saber 3400 supplies and controls the "brawn" to two 40 HP shunt wound Louis Allis DC motors.

In addition to the four motors used to raise and lower the leaves, Louis Allis provided a 7.5 HP AC motor to operate the centerlock device when the bridge is in the down position, as well as four 10 HP AC motors for emergency use.



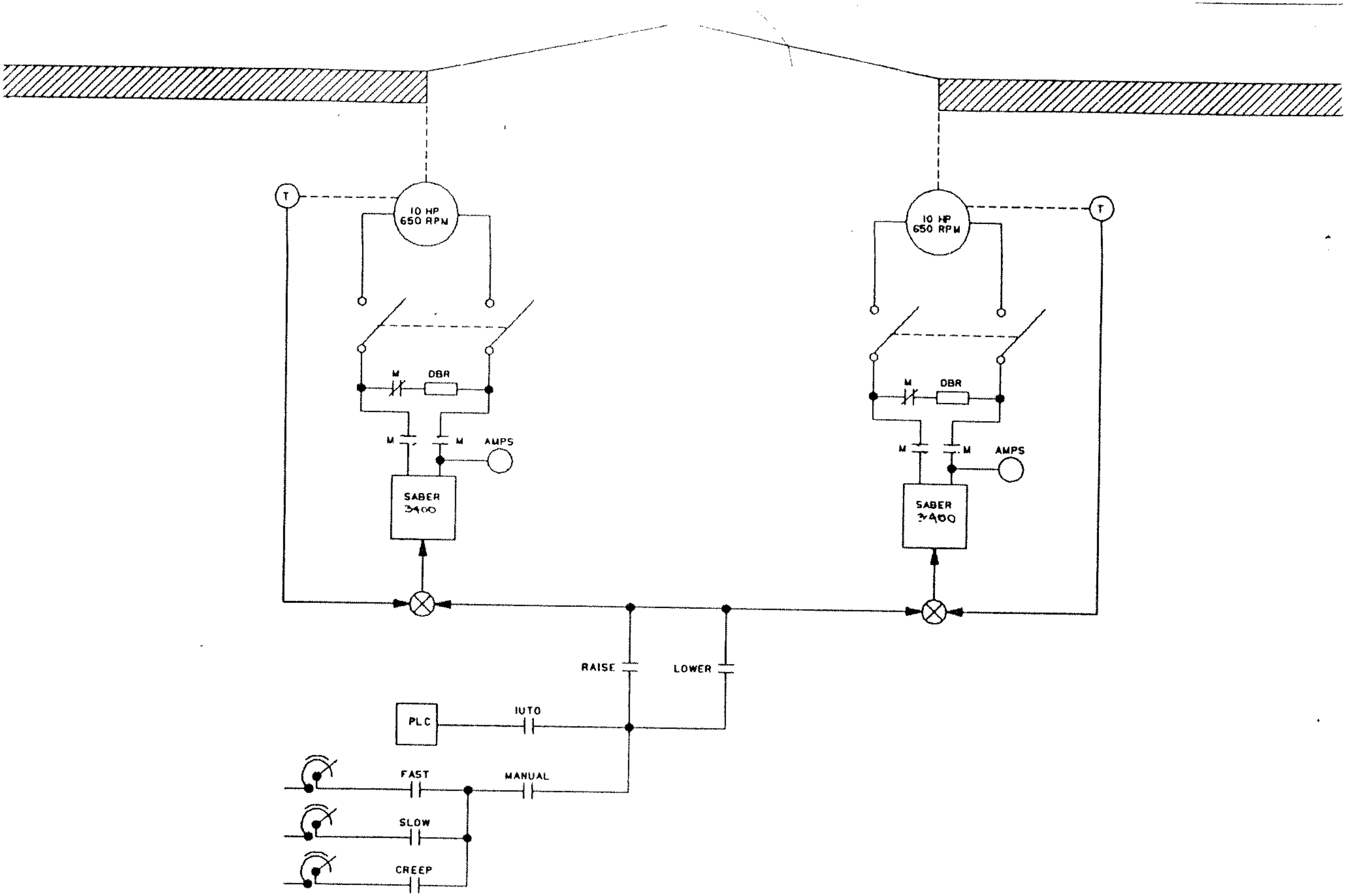


PLANKINGTION AVE
BRIDGE
MILWAUKEE. WI.



CLARK STREET BRIDGE
CHICAGO, ILLINOIS

I:IL_BRIDGE.DRIVE.I



BOCA RUTO,
FLORIDA

H. BRIDGE DRIVE 2