Automated Movable Bridge Drives

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November 4, 1985

## ABSTRACT

This paper will give an overview of the different types of movable bridges and electrical-type bridge controls, and will discuss in detail the design experiences associated with retrofitting an existing bridge with a new drive and control system.

## INTRODUCTION

Highway and railway movable bridges can be broken down into three basic types of structures - Swing, Bascule and Vertical Lift.

### Swing Bridge

The swing bridge turns horizontally about a central pivot. The turn is usually 90 degrees from the closed to open position with the span parallel to the waterway in the open position. (Figures 1 and 2).

### Bascule Bridge

The bascule bridge pivots about one end as the other end raises up and out of the way to clear water traffic. There are single leaf and double leaf bascule bridges. Bascule bridges are classified into two types - trunnion and rolling lift (Scherezer).

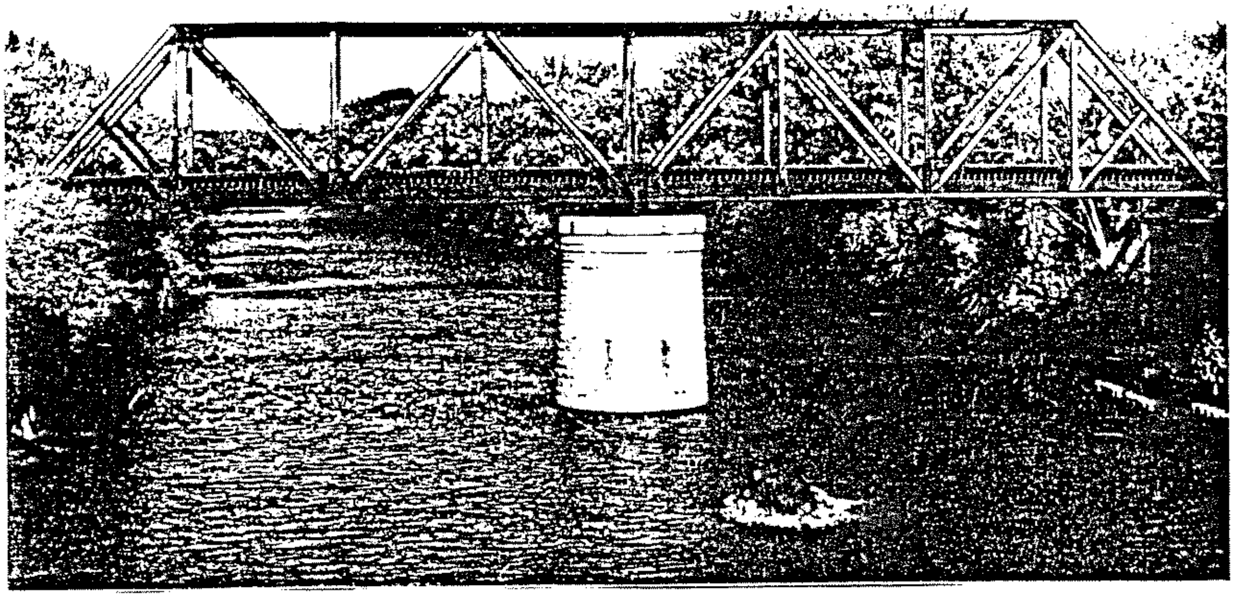

FIGURE I
SWING BRIDGE

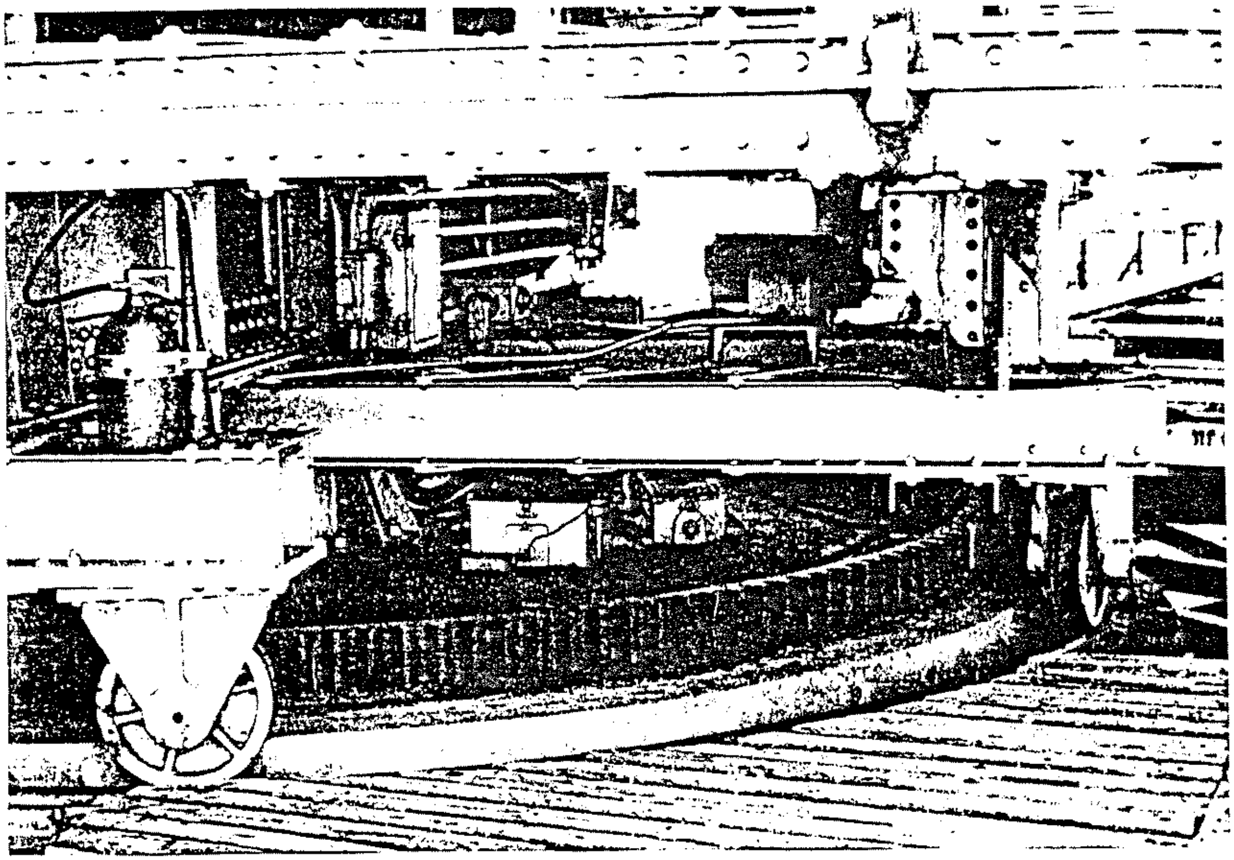

FIGURE 2
BALANCE WHEELS AND RACK
ON CENTER BEARING SWING SPAN

The trunnion-type (Chicago trunnion) bascule bridge has a stationary trunnion. This bridge consists of a forward leaf and a rear counterweight arm which rotates about the trunnion. The operating machinery is mounted on a stationary platform or in what is usually called the bridge machinery room, located below the bridge. This machinery drives the span through a rack and pinion arrangement. The rack is in the form of a 90 degree arc. (Figures 3, 4 and 5).

The rolling lift type (Scherezer) has the bridge roll back on a track as the opposite end rises. The machinery platform tilts along with the bridge. (Figure 6)

Vertical Lift Bridge

The vertical lift bridge is raised horizontally from both ends. The ends ride up towers to a height sufficient to clear water traffic. There are two types of vertical lift bridges - the span drive bridge and the tower drive bridge.

The span drive bridge has the operating machinery located on the span itself. Through line shafting, a single motor can normally drive both ends of the bridge.

The tower drive bridge has the operating machinery located in the end towers. Duplicate sets in each tower raise and lower the bridge span.

Control Systems

There are two types of control systems - Hydraulic and Electrical. Both systems can be designed for manual or semi-automatic operation.

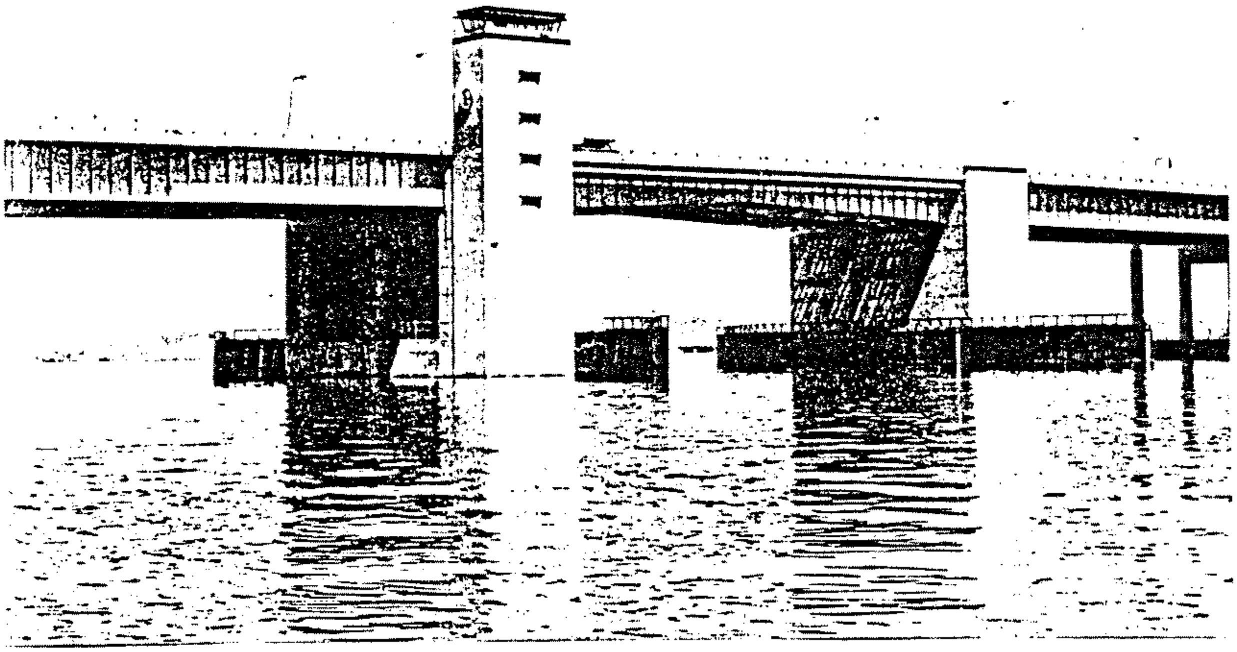

FIGURE 3 BASCULE BRIDGE

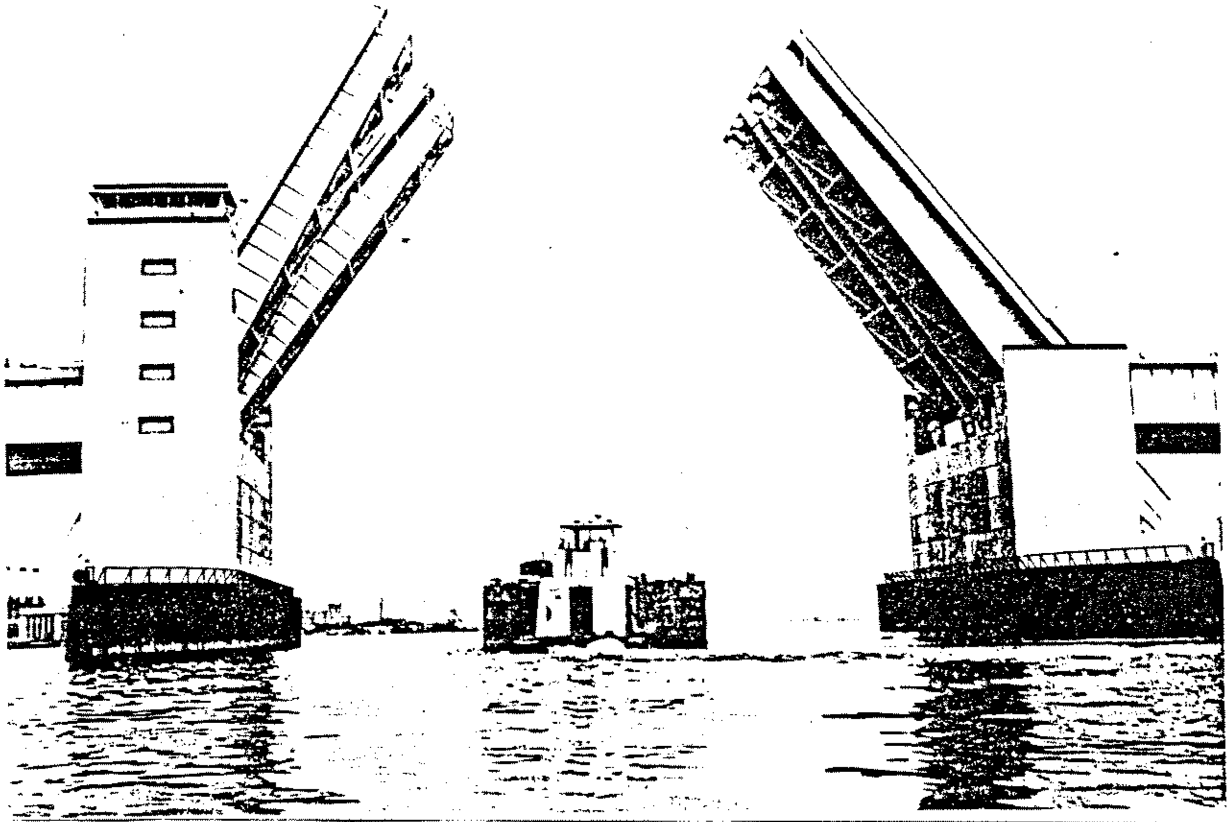

FIGURE 4 TWIN LEAF BASCULE

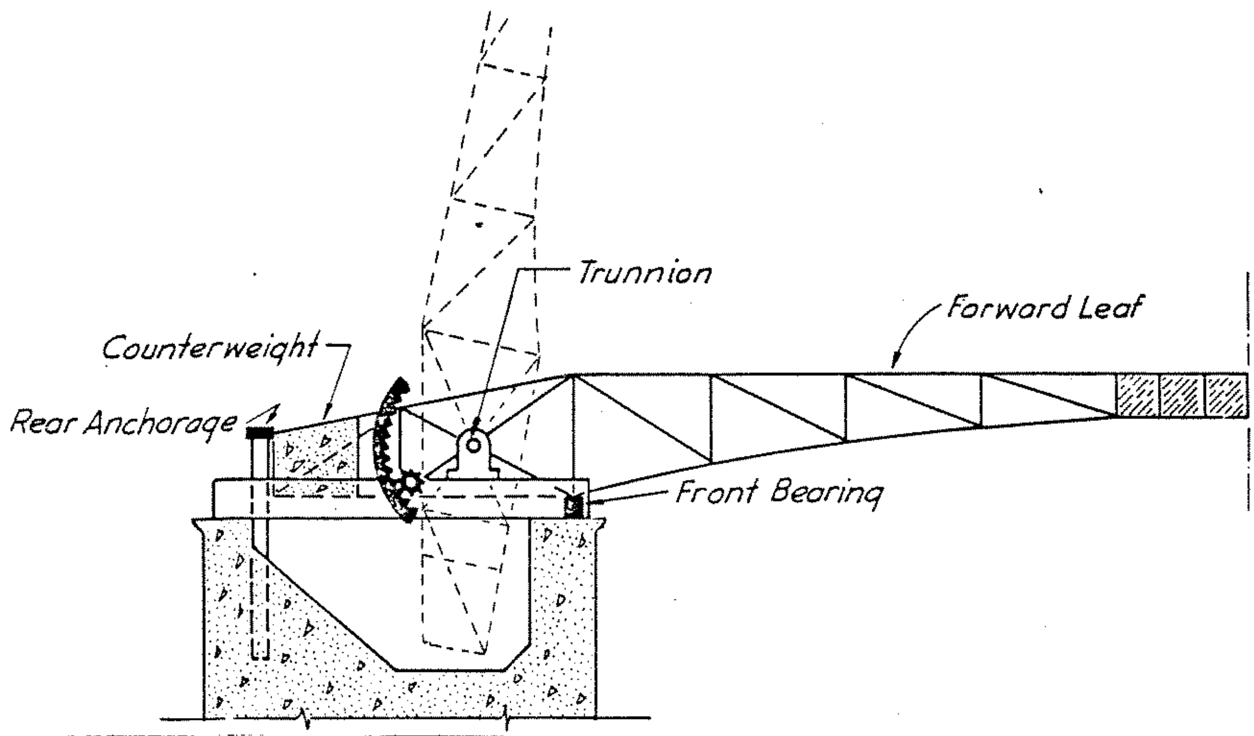


FIGURE 5 TRUNNION BASCULE BRIDGE

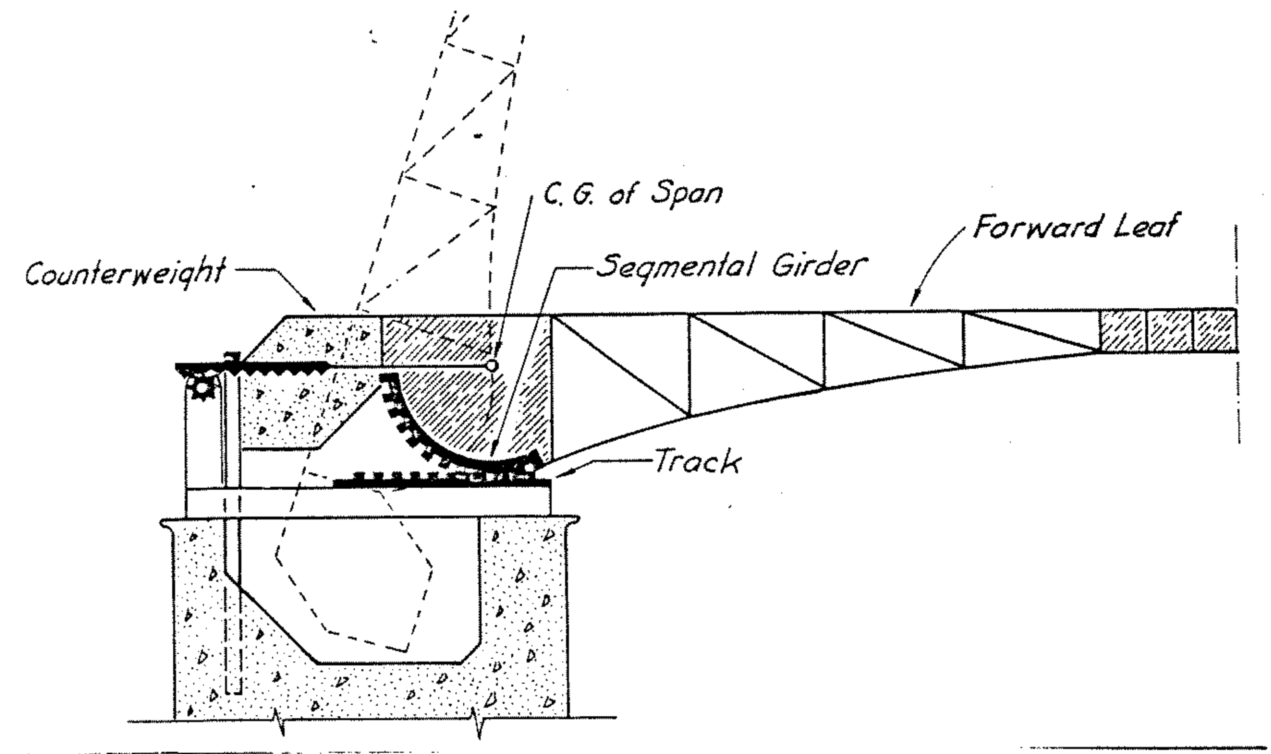


FIGURE 6 ROLLING-LIFT BASCULE BRIDGE

## TYPICAL PROCEDURE TO INSTALL A NEW CONTROL SYSTEM ON AN EXISTING BRIDGE

In recent years many bridges constructed in the first half of the 20th century have been rehabilitated to provide state-of-the-art control and drive systems.

One such project recently completed by Envirodyne Engineers, Inc. (EEI) was the Clark Street Bridge over the Chicago River in downtown Chicago, Illinois. The renovation project took almost five years from start to finish. The Clark Street Bridge was originally constructed in 1931. This double leaf bascule bridge was rehabilitated with new drive motors and control systems. Each leaf is operated by two 100 HP DC motors. The two motors are connected in series and controlled by a DC regenerative controller. A second redundant controller is provided for each leaf.

EEI was authorized to proceed with the project in November, 1980. After obtaining record documents, a thorough inspection of the existing equipment was made in January, 1981.

An evaluation of available systems and technologies was made as they related to the existing bridge's mechanical and electrical equipment and the possibility of using the existing equipment in the rehabilitated design.

In July, 1981 the Final comprehensive report was issued to the City of Chicago Department of Public Works summarizing the results of EEI's inspection, alternatives for rehabilitating the drives and control systems complete with cost analysis, and EEI's recommendation for which alternative should be selected.

A short period of discussion with the City on EEI's recommendation then commenced, culminating in the authorization to proceed with the design of the recommended system in April, 1982.

The design of the new control and drive system was closely coordinated with the City and the design package was issued for construction in the spring of 1984. The engineering portion was completed within nine months.

In the fall of 1985, construction was substantially completed with minor final punch list items still to be completed.

Throughout the construction phase, there was continuing cooperation between the City, the General Contractor, the Electrical Subcontractor, the Control System Supplier, the Drive System Supplier and EEI to ensure the best available technology was incorporated for this project.

## SELECTING A DRIVE SYSTEM

The major discussion to be made in rehabilitating the bridge was what type of Drive system should be installed both AC and DC systems were considered.

## APPLICATION OF DC DRIVES FOR BRIDGE OPERATION

The regenerative DC drive has been found to be ideally suited for variable torque application such as that encountered in movable bridges. The torque regulation is through current regulated power which results in smooth stable machine operation. The regenerative system provides the ability to hold back during conditions of severe load, such as high winds or heavy rains. Stable operation is maintained through the entire speed range, full speed opening to full speed closing either motoring or holding back at any bridge position during any cycle.

DC regenerative drives allow the motor to act as brakes when lowering the bridge, reducing wear on the service and emergency mechanical brakes while providing the most efficient use of power available with adjustable speed drives.

One type of system is the patented fast response four quadrant rectifier control system as manufactured by the Louis-Allis Company.

A closed loop armature current regulator is used as the fundamental building block to control torque to the motor shaft. In bridge applications, this is coupled with a position indication signal from limit switches or a selsyn indicator to control speed.

## APPLICATION OF AC DRIVES FOR BRIDGE OPERATOR

An alternative to DC drives is the utilization of an AC wound-rotor motor with a power rated thyristor control system.

A wound-rotor motor provides the ability to modify the rotor resistance from outside the motor while it is running, thus changing the motor's characteristics. This is possible because the rotor loops are actual windings of copper wire layed in slots in the rotor's magnetic steel. The ends of the wires of each winding are connected to copper slip rings placed around, but insulated from the rotor shaft. These smooth, unsegmented rings are contacted by brushes enabling the connection of external resistors to the rotor windings. Each different value of rotor resistance causes a different speed vs. torque characteristic. The optimum resistors for starting the particular bridge load can be chosen, allowing the engineer to select torque characteristics not normally available. Much of the motor heat is dissipated in these external resistors, resulting in a cooler operating motor.

The span speed is regulated through the action of gating amplifiers and line thyristors. By means of controlled proportional gating of the line thyristors, the AC drive motor is obliged to run at sub-synchronous speed. By using an image set of thyristors and gates, static reversing of the drive is assurred without the use of reversing contactors.

A DC permanent magnet tachometer together with a position indication signal from limit switches or a selsyn indicator.

One of the most publicized features of the thyristor drive is the so-called "ramp function". This is simply a predetermined program for motor speed. An electronic circuit starts the motors and applies torque as required to increase speed linearly from zero to running speed over some prespecified time period. This is the "ramp up". Then the curve is flat, indicating constant running speed. Near the end of travel, the motors are linearly decelerated to either zero (bridge full open) or some slow crawl speed (bridge seating), applying counter-torque through electronic motor reversing as necessary to force the motor to follow this preprogrammed "ramp down". One type of system that we used was the Class 22-A501 Controller manufactured by the Westinghouse Electric Corporation.

This system was used on the Columbus Drive Bridge over the Chicago River in Chicago, Illinois. The Columbus Drive Bridge is the longest drawbridge in Chicago. Designed in the "Chicago style", it is a double leaf trunnion bascule bridge. Even though each movable leaf weighs 6.3 million pounds, it can be raised or lowered with only one 150 HP motor under abnormal operation. There are two 150 HP motors which operate each leaf.

Each motor is controlled by an AC thyristor drive and each is backed up with a magnetic controller. The bridge is also equipped with two 40 horsepower emergency motors for each leaf which are controlled by magnetic controllers.

The City of Chicago, Department of Public Works selected a DC regenerative drive system for the Clark Street Bridge project.

## OPERATIONAL SEQUENCE FOR BRIDGE OPERATION

The opening and closing of most bridges is accomplished utilizing a manual control scheme or a semi-automatic control scheme and one operator. Fully automatic operation and remote operation are usually not recommended for most applications for safety reasons. A normal sequence of operation is as follows:

1. The bridge operator checks traffic, energizes the traffic signals and lowers the traffic gates.
2. The bridge operator verifies that the bridge is free from traffic and lowers the vehicle barriers if the bridge is so equipped.
3. The bridge operator pulls the span locks.
4. The bridge operator releases the machinery brakes.
5. The bridge operator raises the bridge. The motor (service) brake is usually interlocked with the operating circuiting to automatically release when the bridge drive is energized.
6. The span will automatically accelerate to top speed and automatically decelerate to stop at the open position for semi-automatic control.
7. In the manual control scheme, the operator determines the leaf speed, accelerates and decelerates the leaf, and stops at the open position. Limit switches are also provided to prevent over travel of each leaf.
8. The bridge operator sets the machinery brakes.

When the water traffic is clear and the bridge is to be closed, the bridge operator reverses the above operation. Final seating of the bridge is done by the bridge operator after the bridge is stopped in the nearly closed position.

Electrical interlocking to prevent operation of a step, unless the previous step has been completed, should be provided for the control scheme to ensure the proper manual procedure is followed.

Some electrical interlocks may require bypass switches to allow operations when a previous step has not been correctly completed, or for maintenance purposes. These bypasses should always be key operated to prevent their use in "normal" operation.

A semi-automatic control scheme was installed on the Clark Street project. The controls include a secondary control console in the south leaf bridge house to control the south leaf as well as the main control console in the north leaf bridge house which controls both leafs.

## DESIGN AND CONSTRUCTION EXPERIENCE

It is extremely important that the Design documents place the responsibility for supplying the total drive and control system to the electrical subcontractor for the bridge. This is to alleviate many problems which have arisen in recent years when the drive system is supplied through the mechanical subcontractor and the bridge control system is supplied through the General Contractor. On one of our bridges, the General Contractor purchased the bridge control system from a control panel manufacturer who bought the electrical and electronic components from a control manufacturer. The General Contractor then hired an electrical subcontractor to install the system.

We feel that these problems were avoided in the Clark Street Bridge renovation by preparing the electrical specification to entrust sole responsibility for the Drive, Control system and installation to the Electrical Subcontractor. The City of Chicago rennovation contract for this bridge was still with one General Contractor.

## SUMMARY

This paper has presented a brief overview of bridge control. The consulting engineer must work closely with the owner to ensure that the bridge control system can be operated and maintained within the capabilities of the owner's engineers and maintenance personnel.

## REFERENCES


1. Fast Response Four Quadrant Rectifier Control, Donald E. Vollrath, Technical Consultant, Litton Industrial Products Ins., Louis Allis Drives and Systems Division, IEEE #CH1575-0/80/0000-821

2. Westinghouse Electric Corporation bulletin IL22-501-TB. Class 22-A501 Traffic Bridge Control

3. City of Chicago, Department of Public Works, Bridge Division.

4. Bridge Inspector's Training Manual 70, U.S. Department of Transportation, Federal Highway Administration, Washington, D. C. 20590.


## AUTHOR

Irwin C. Smiley, P.E., was born in Chicago, Illinois in 1940. He received his B.S. degree from Roosevelt University, Chicago, Illinois in 1962. He worked for two manufacturers and several consulting engineering firms.

In 1979 he went to work for Envirodyne Engineers, Inc., Chicago, Illinois, where he is a Senior Associate and head of the Electrical Engineering Department.

Mr. Smiley is currently a Vice President of the Illinois Society of Professional Engineers, senior member of ISA and IEEE; a member of AEE, CEE, ISPE, NSPE, Chicago Lighting Club, and Roadway Lighting Forum. He is a registered Professional Engineer in the states of Illinois, Indiana, Louisiana, Maryland, Missouri, New York, Tennessee, Texas, West Virginia, and Wisconsin. Mr. Smiley is a Certified Energy Manager and a Value Engineer.