Movable Bridge Electrification

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Abstract

Most movable bridges rely on electrical power to control and operate the mechanism that causes the bridge to move. The methods of control, the general power distribution, emergency or standby power sources and an overview of operating characteristics will be discussed in this paper. This presentation is a general overview of some of the different operating systems that will be discussed in detail by other authors. It will begin at the service entrance and proceed through the system to the bridge operating equipment.

Electrical Service

The quality and type of electrical service available depends upon the bridge location. An isolated rural area may only have a single phase service readily available unless costly extra conductors are installed for some miles back to a three phase line. An area close to population centers normally has any voltage or phasing that is required when the proper transformation is installed. Remember, the higher the voltage, the lower the current peaks and the smaller the electrical power components can be. The normal preferred voltage is 480 volts, 3 phase 60 hertz with transformation used to deliver 120 volts for receptacles and control. If the system is configured wye, the lighting will often be 277 volts.

A standby generation system is normally included in the bridge power system to provide operational capability when the normal system fails. This unit may be mounted on the bridge itself or on property near one of the bridge approach ramps.

It should be noted that a good grounding system is essential for personnel safety and proper operation of microprocessor based controls. Check your grounding systems, just because you are near water does not mean you have a low resistance ground. A low resistance (5 ohms or less) ground system, coupled with an efficient surge protector installed at the service entrance, will prevent many system component failures that might occur. A simple ground resistance check is well worth the expense when it prevents future component damage.

The sizing of service components depends on the total electrical load and the voltage fluctuations the utility will allow its system to be subjected to. In some cases a soft utility system may require reduced voltage starting equipment, soft start systems and even filters to reduce any harmonics that might be fed back into the system by solid-state components.

The location of the nearest service point must be considered when selecting the location for the bridge control house. It is not considered prudent to install a main power supply as a submarine cable across a riverbed when a simple reversal of the control house location could avoid it.

Bridge Power Distribution

The service cable normally terminates in a main distribution fused switch or circuit breaker. At this point the emergency generator is usually connected to the system by a suitably sized automatic transfer switch. This switch controls the generator and normally provides a means of exercising the generator periodically.

Standby Generator

The generator is usually fueled by the most readily available source, be it gasoline, diesel fuel, natural gas or propane. A preferred fuel, for safety in handling and storage, is diesel fuel. However, diesel installation users *must be cautioned that such engines should only be operated at 50% or greater* load as periods of no-load operation cause the engine to become loaded with carbon and unreliable. The best way to test an emergency generator is to pull the main service switch, simulating a power failure, and let the system operate on emergency power. Performing this test at least once a month, with the generator under load for at least one hour, is what is normally recommended by most manufacturers. A stepped resistance loadbank can be installed to test the generator when the operating load cannot be practically applied for a long enough period. Do not forget that engines, with more volatile fuels, located within the bridge structure may require fire suppression systems to protect other control components in the area.

Secondary Distribution

After the transfer switch is the main distribution system for the bridge. This may be a main distribution panelboard or a motor control center, depending on the size of the system. If a panelboard is used the motor controls for bridge span locks and drive system must be supplied as separate enclosures. If the motor control center concept is used, the motor controls are an integral part of the center. Circuit breakers or fused switches in either the panelboard or motor control center are used to protect the distribution systems for bridge lighting, traffic control systems and navigation lighting. Transformation may be required to provide the correct voltage for lighting and traffic control. Before the main drive system is discussed the other systems will be described.

Let us review the method of distributing the necessary electrical wiring throughout the bridge structure or in the case where power or control is required to cross the channel, how it can be protected from water and damage. Salt water environments create extreme corrosion problems requiring heavily galvanized conduit, plastic coated conduit, PVC conduit buried in the bridge structure and PVC jacketed, interlocked armor, cable. The water crossing can be achieved by using aerial cable spanning the area from suitable towers, submarine style cable laid on the channel bottom or prefabricated duct lines assembled on shore using PVC duct and buried in a trench cut across the channel. On the bridge structure across flexible joints and at any motor, PVC covered flexible metal conduit should be installed. A type of flexible non-metallic conduit has been developed and approved for certain types of installations. Caution must be used with plastic products that are exposed to the harsh southern sun, special ultraviolet resistant formulations are required or rapid deterioration will occur, resulting in brittle fragile plastics that are easily broken. Hot dipped galvanized products should always be used for metal supports and hangers. Heavy duty flexible cords are also required in some applications and again jacket formulations must be scrutinized for sunlight resisant qualities. Some of the best distribution systems use concrete encased PVC conduit with PVC coated steel conduit in exposed areas and PVC coated flexible conduit where required.

There are different types of bridge motion that result in particular control requirements. These motions are vertical lift or elevator type control, swing bridges readily susceptable to wind action and the bascule bridge with its overhauling characteristics. All of these control systems require position feedback, speed control, acceleration control and deceleration feedback. For years these controls have been manually operated but now the newer systems are micro-processor based using sensor feedback to regulate speed and positioning. A number of bridge systems have to be integrated to produce a smoothly functioning safe operation. These systems are the traffic control devices, such as traffic control lights, warning siren or bell, traffic barriers or gates and sometimes marine navigation control lights. The usual sequence involves the operation of the traffic lights and warning siren first. This is followed at a specific interval with the closing of the traffic barriers. The closing of the traffic barriers then allows any span locks to be released and the bridge opening mechanism to operate. If marine traffic lights are used they are activated after the span is opened.

Span Drive Systems

Bridge span drive operating systems are available in different configurations. Each installation requires some means of starting the span moving (a high torque requirement), controlling the mid cycle speed of the span (wind effects and an overhauling load) and easing the span into the fully open or fully closed position, without driving it through the stops. The options available are as follows:

- Alternating current, induction motor control
- Eddy current coupling, induction motor control
- Alternating current, two or three speed induction motor control
- Alternating current, wound rotor control
- Adjustable frequency, induction motor control
- Rectified direct current, direct current motor control

Each of these options has its advantages and its shortcoming.

Alternating Current, Induction Motor Control

This system uses a standard single speed induction motor. The motor has one constant output speed and any other speed control is accomplished by gearing or having the motor drive a hydraulic unit with a variable output. The load requirements must be compared with the available motor speed-torque curves, to arrive at a suitable unit for use as the span drive. The brakes are then used to allow the span to coast to a stop at the end of travel.

The motor starter or controller for this type motor may be one of the number of versions available. The only common requirement is that it be a reversing model. These starters are defined as follows:

1) Full voltage, reversing which is the most common for single speed motors and imposes the full starting current surge, up to 6 times full load current on the utility system.

2) Reduced voltage, reversing is required where the utility system cannot tolerate any starting surges on the system. The controllers for this type of starting are part winding, wye-delta and auto-transformer. The first two require specific purpose motors, while the latter operates a squirrel cage or standard induction motor. The part winding and the wye-delta configuration require the motor winding leads be all brought out to the connection box so that the winding connection configuration may be changed by external contactors. In the case of part winding the motor has two windings with the first step connecting one winding to the system, which will require about 65% of the normal locked rotor current of the motor from the line but only delivers 45% of the motor locked rotor torque. The second winding is connected in parallel with the first, after a timed interval, and the motor develops full torque but the starting current demand on the system was held to 45% of normal.

   The wye-delta starter operates with a delta wound squirrel cage motor that has the leads brought out so that it can be started wye connected. The wye connection results in approximately 58% of full voltage, 33% of locked rotor current and 33% of full torque.

   The problem with both these systems for bridge operation is the large number of contactors required to provide reversing capability, the motor having to be sized so that the span breakaway torque is 33% to 45% of the full motor torque and the complexity of connections in the starter that the maintenance personnel would have to deal with. The autotransformer provides the highest starting torque per ampere required, reduces the inrush current to at or below full load current and requires only a standard squirrel cage motor. The reversing is relatively easy as only three leads are brought out of the motor. The motor may still require oversizing to provide sufficient breakaway torque but this is now in the area of 20% to 30% not 50% to 60% as for the wye-delta and part winding configurations.

If an AC induction motor drive is being considered, the autotransformer started, reduced voltage system appears to be the best solution where reduced voltage starting is required.

Eddy Current Coupling, Induction Motor Control

This system uses a constant speed induction motor and a variable speed, electromagnetic coupling. The coupling operates by varying the strength of the magnetic field that electrically connects the mechanically separated rotating members of the unit. This unit may require water cooling, depending upon the size installed. The magnetic or eddy current coupling relies entirely upon the braking system to control the stopping of the span and reversing creates its own special problems of tachometer feedback. This control system is not highly recommended for this type of intermittent operation.

Alternating Current, Two or Three Speed Induction Motor Control

The starters for this type of motor were discussed in the section on A.C. induction motors. It is indicated there, that the problem of reversing the system becomes very complicated, the motor speeds are fixed and final positioning requires careful application of the system brakes. It can be very difficult to jog the span the last few inches if the brakes were applied so as to stop the span too soon.

Alternating Current, Wound Rotor Control

This is a system that has been used for span drives for some time. It is based on an induction motor with the rotor windings brought out externally by means of slip or collector rings. Resistance of the rotor windings can be increased or decreased by the addition or subtraction of external resistors. The standard drum type speed control is used in conjunction with these resistors to give definite speed steps.

The drawbacks to this control are brush maintenance, fixed speed steps, resistor maintenance and smooth operation being dependent on a good bridge operator. The addition of microprocessor based controls and a reliable position feedback system can be used to overcome operator inputs as all the operator would do is push a bridge "open" or bridge "close" control with the processor doing all the control functions.

Adjustable Frequency, Induction Motor Control

This control system uses an induction motor and varies both the frequency and voltage of the power being supplied to the motor to vary the motor's speed. Depending on the heat rise of the motor windings and torque requirements of the drive application it may use a standard "off the shelf" motor or a high starting torque design "D" unit.

The controller is made up of solid-state, frequency synthesizing, electronic components, that require maintenance personnel with specialized training to repair. The proven reliability of these units in industrial applications does indicate that these units can operate successfully under adverse conditions with minimal maintenance. These units are susceptable to high humidity and high temperature, which dictates that the area the controller occupies must be air conditioned in Florida. The motor and the control cabinet can require high airflows during periods of slow speed operation which may introduce some design problems. This system is readily adaptable to micro-processor or mini-computer control.

Speed adjustment can be preset to follow a specific operating curve or is readily adjustable at any time by means of a rheostat.

Rectified Direct Current, Direct Current Motor Control

The rectifier system for this control uses silicon controlled rectifier bridges that provide whatever level of power output is required to produce the required motor output torque. The motor used is usually a mill duty d.c. unit that can absorb the mechanical stresses, similar to the operations of a metal stamping press, that can be imposed on it by bridge operation. Both this unit and the adjustable frequency unit are designed to deliver 150% of output torque at any point in the speed range. The d.c. unit has one advantage, it will regenerate under overhauling loads and will pump the excess power back into the system. This can result in a net power savings over other drive systems for a given application.

Some disadvantages are the brush and armature maintenance required which is somewhat higher and more critical than that for the slip rings on wound rotor motors.

Drive Summary

There are installations of each one of these drive systems throughout the country. The most common of these are the wound rotor or the d.c. drive unit. Each application must be reviewed and the most suitable system selected. Factors to be considered are:

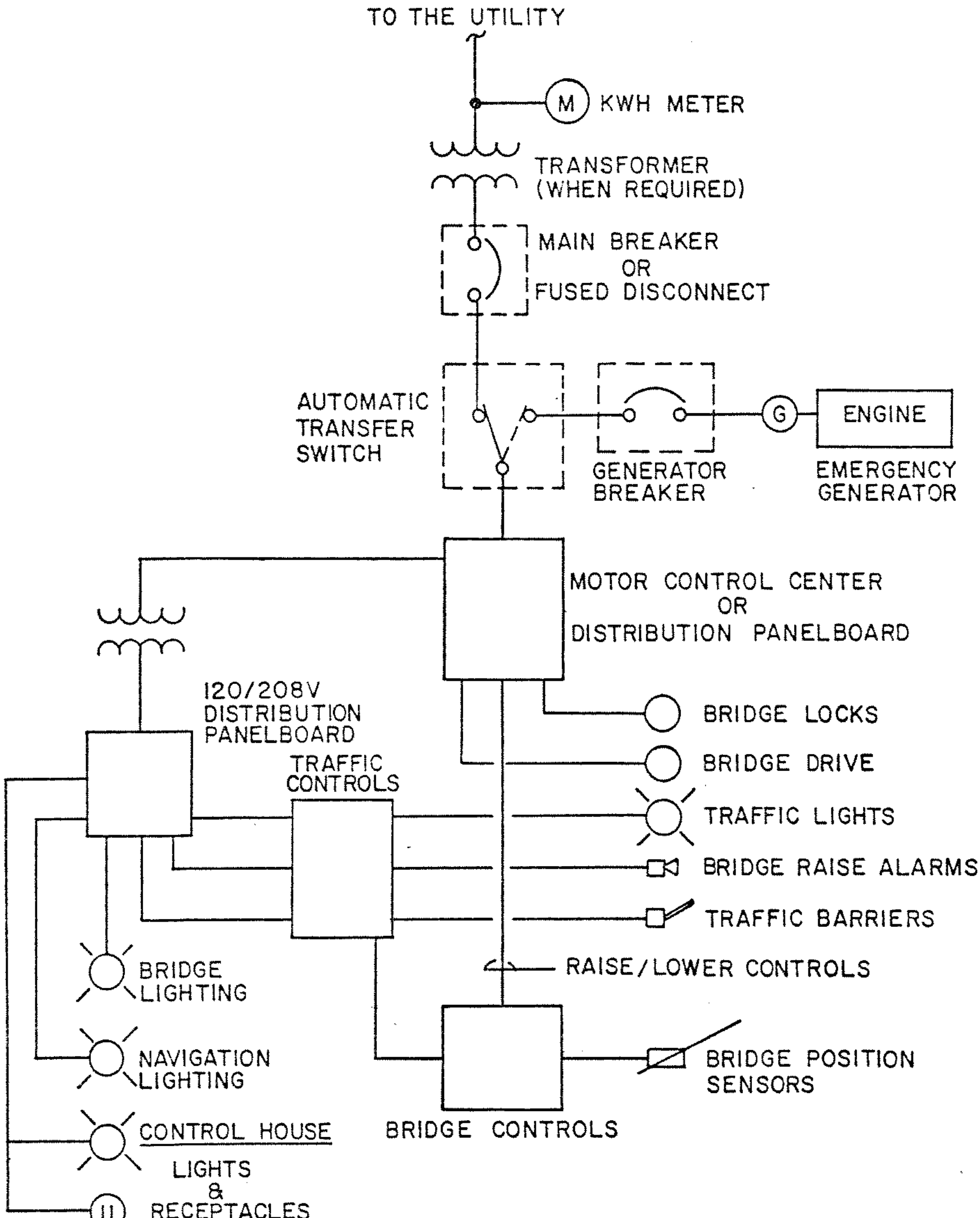
- Lift span operation
- Susceptability to wind loads
- Type of control (operator, micro-processor)
- Capabilities of the maintenance staff
- Frequency of bridge operation
- Proximity to a major parts supply area

When all these items are considered carefully, the resulting drive system should give reasonable, trouble-free service.

Do not forget the other auxiliaries required for a lift span such as marine radios, signal horns, control house lighting, convenience receptacles and provisions for mechanical operation if all electrical systems fail.

Please note the attached generic single-line diagram of a typical bridge that has been included for reference.

END



BRIDGE ELECTRICAL BLOCK DIAGRAM