CLASS 22-A501 TRAFFIC BRIDGE CONTROL

Features of the Control System

The 22-A500 line thyristor AC traffic bridge control makes use of power rated thyristors to regulate the flow of AC power to polyphase motors.

By means of controlled proportional gating of these line thyristors, the synchronous minded 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 assured without the use of reversing contactors.

A DC permanent magnet tachometer provides the means for controlling speed right to zero.

The circuitry is easy to understand. The use of thyristors to replace saturable reactors in the line of polyphase motors provides several advantages including a reduction in weight of control and floor space required by a factor of two. Number and connections of power cabling is reduced as well as installation time for the control.

Protection

Phase failure or reverse phase shuts down the drive and provides visual indication.

Inverse time overload protection for the motor or motors.

Emergency stop pushbutton may be provided to de-energize the control in case of an emergency.

Fast acting circuit breakers, coordinated with thyristor I^2t rating, provide sub-cycle as well as multi-cycle fault current protection for the thyristors.

Span Motor Thyristor Regulator

The span is speed regulated through the action of gating amplifiers and line thyristors.

The schematic diagram shows the arrangement of the thyristors in the AC motor primary power circuit. The thyristors operate as gated rectifiers that can be controlled to steplessly vary the voltage applied to the motor from zero to full voltage. Since the thyristor is fundamentally a rectifier, its control is limited to a half wave of AC voltage. Using two thyristors back to back, complete control of full wave voltage is possible. Thyristor pairs 1THF-2THF, 4THF-5THF and 3THFR-6THFR are used to control the voltage applied to the motor to develop "open" torque and pairs 1THR-2THR, 4THR-5THR and 3THFR-6THFR control the voltage to develop "close" torque.

Gate control of the thyristor pairs causes them to function as static reversing means and in operation of the bridge all open-close power switching is accomplished without contactor operation. The line contactor is an isolating contactor that remains closed during all normal open-close operations and opens only when safety protective devices operate to remove power from the drive or following a period of inactivity.

When the span control switch is moved to open, power is applied to the motor. The reference input established by the ramp function generator advances the gate firing angle applied to the open thyristors. The drive will accelerate until the feedback voltage from the tachometer is nearly equal to the reference from the ramp function generator. It will then continue to accelerate as the reference rises.

In closing operation, the same sequence occurs except that the close thyristors are initially gated.

If the span must be driven down, the "close" thyristors will be fired the required amount. If the load is overhauling, a small increase in tachometer speed and feedback voltage will fire the "open" thyristors applying counter torque to the drive to maintain the lowering speed called for by the reference.

A permanent slip resistor in the motor secondary circuit is designed to limit the starting torque. The response of the 500 line thyristor control is such that the drive is nearly stopped electrically during the time the ramp function generator is returned to off and the brake sets, thus minimizing brake wear and maintenance.

Regulating System

The motor is speed regulated through the action of a regulator assembly and a thyristor power assembly which form the heart of the system. A speed reference from a pilot generator is matched to a reference from a ramp function generator within the regulator assembly. The output of the regulator assembly controls the thyristor outputs that are in series with the stator of the motor. Control of the firing angle of these these thyristors controls the voltage applied to the line terminals of the motor and thus the speed for a given torque requirement.

Two basic functions are set into the regulator assembly. These are reference and speed. The setting of each of these will be covered independantly.

Speed - The pilot generator that supplies the speed signal has an output proportional to speed of rotation. A portion of this is taken off voltage divider 40R and 41R and applied to terminal 41 of the speed controller in the regulator assembly. This voltage divider is omitted on low speed drives.

Reference - The reference must supply sufficient current to the summing junction to sustain the output of the regulator at the desired level plus the current to overcome the pilot generator feed back.

This reference supply is a ramp function generator which produces a gradually increasing voltage over a preset time and will reduce this voltage gradually over another preset time. The ramp output voltage is determined by the reference voltage applied to the ramp function generator. For full speed operation approximately +10 VDC is applied to terminal 39 of the ramp. The ramp time can be adjusted by means of potentiometer 6P on the RFG module. It is usually set at the factory for 10 seconds.

A500 Speed Controller - The A500 speed controller is a PI controller. This type I controller has a fixed lead of 25 MS in internal feedback. The tachometer feedback is applied to input 41 which has an adjustable lead and a small filter. The lead is adjustable by jumper 1J.

Dynamic adjustment is by means of the integrating time constant of the speed controller and is adjustable by means of jumper 2J and potentiometer 5P.

Positive limit on the output is fixed by board components. A similar negative limit can be obtained by jumpering 51, 47 and 17. An alternative negative limit can be obtained by supplying the appropriate level to terminal 51, or by connecting a potentiometer between terminals 47 and 17 with terminal 51 connected to the wiper. Terminal 49 is also available for external limiting.

Integrator reset is accomplished by grounding terminal 33 or 35. A +10V ± 2 V signal is required.

A500 Gate Pulse Generator - This card contains six identical phase shifting stages, a common input limiter, and a clock pulse oscillator.

Phase Shifting Stages -- The AC synchronizing voltage is delayed 30 degrees by a passive filter to achieve a cosine relation to line voltages. The cosine voltage is one of three inputs; the others being a bias voltage and control voltage (-Vc). Phase control over 120 degrees is achieved by allowing Vc to change from 0 to -8.0 volts. Pulses are set at 60 degree increments as dictated by the phase relationship of AC synchronizing inputs.

Input Limiter -- Without a limit on control voltage, pulses from the phase shifters can be advanced until they randomly extinguish. This is prevented by an internal limit circuit which limits phase advance to 60 degrees.

Clock Pulse -- The clock pulse oscillator contains a programmable unijunction transistor and associated components. Pulse repetition rate of 10 kHz is determined by the bias level and RC time constant. Gate pulses for thyristors are generated at the CP rate during the 5ms permissive interval from the phase shifters.

A500 Forward Pulser - This card contains six identical pulse shaping stages, and a circuit to inhibit all pulsing.

Pulse Shaping Stages -- Each pulsing stage is driven by an expandable 4-input NAND (one half of an MC-661). Logic inputs to the NAND are generated by the A500 GPG and A500 RP printed circuit boards. Any 0 input to the NAND holds the output 1, while with all inputs 1 the output is 0. Output pulse width is approximately 30 us as determined by the discharge time constant of the circuit. Gate pulses are coupled through an externally mounted transformer tied between terminals 37 and 1. The output is a train of 30 us wide pulses at a 10 kHz rate lasting for 5 ms. When correctly phased the six pulse trains are created at 60 degree increments with pulser one output leading pulser two ..... pulser five output leading pulser six output.

Pulse Suppression -- A gate pulse suppression input V_{51-31} greater than +7.0 volts is required to produce any gate pulses. Less voltage at the GPS input turns 1TR off and suppresses the gate pulses. The collector voltage of 1TR is taken from RI to the A500 RP printed circuit board where it performs the same pulse suppression function.

A500 Reverse Pulser - This card contains four identical pulse shaping stages, an inverting amplifier, and a circuit which produces reversing logic signals.

Pulse Shaping Stages --Each pulsing stage is driven by an expandable 4-input NAND (one half of an MC 661). Logic inputs to the NAND are generated by the A500 GPG and the A500 RP printed circuit board. Any 0 input to the NAND holds the output to 1, while with all inputs 1 the output is 0. Output pulse width is approximately 30 us. Gate pulses are coupled through an externally mounted transformer tied between terminals 11 and 1. The CP (clock pulse) is a signal which switches from 0 to 1 at a continuous 10 kHz rate, while 1GP is a phase controlled 1 of 5 ms duration generated once each cycle of line voltage. The output is a train of 30 us wide pulses at a 10 kHz rate lasting for 5 ms. When correctly synchronized the pulse output from one leads that from two by 60 degrees, the output from 2 leads 4 by 120 degrees, the output from 4 leads 5 by 60 degrees, and the 5 output leads 1 by 120 degrees. All pulsing is suppressed by a signal from the A500 FP.

Inverting Amplifier -- A negative reference input (-Vc) is required to the A500 GPG to phase on gate pulses. For reversing drives the required inversion of reference polarity is provided by the proportional IC operational amplifier 1-OA.

Reversing Logic -- Either the forward pulser or the reverse pulser is allowed to generate gate pulses at a given time, and when switching from one to the other a fixed minimum inhibit time is provided when neither is allowed to produce gate pulses. The state of logic signals FO and RO are determined by the input polarity to 2-OA (a 20 MV error, TD to PSC, is sufficient to saturate the amplifier). Any change in FO and RO generates a reversing logic (RL) signal which inhibits all pulses for a minimum of 2 ms. The RL signal is produced by two identical time delay stages. During steady state operation RL = 1.

D.C. Power Supply - Unregulated ± 24 VDC Supply -- AC input power to the unregulated +24 VDC supply is provided to terminals 39 to 49 by three gate control transformers. The AC voltage supplied is approximately 18V RMS. This voltage is rectified to +24 VDC and designated as PSP, and the -24 VDC as PSN. PSP and PSN supply DC power where the voltage regulation and ripple are not critical, such as gate pulse power.

Regulated ± 15 VDC Supply -- These supplies are series regulating, current limiting types. Each supply is short circuit proof for a moderate period of time. Vernier voltage adjustment is provided by potentiometers 1P and 2P. The ± 15 VDC supplies are used to provide power for the gate pulse generation and shaping circuits, and for the controller modules used in A500 systems.

Phase Sequence and Phase Loss Detection -- AC voltage is applied to RC network from input terminals 47 and 49. With proper phase sequence (and no missing phase) the amplitude at the output of the RC network is insufficient to break over zener diode 14D and trigger thyristor 1TH. With incorrect phase sequence or a missing phase the voltage from the RC network increases significantly and will break over the zener diode 14D and trigger thyristor 1TH. With 1TH conducting, indicator lamp 1IL on the handle of the power supply board will light up, and the voltage at terminals 51 and 57 will change from approximately +25 volts to approximately 0.5 volts. Thyristor 1TH can also be triggered by external signals brought into terminals 37 and 53.

Thyristor - All power thyristors are mounted on solid contact heat sinks. The use of two thyristors in a phase in anti-parallel connection insures symetrical gating of each half cycle. Thyristor heat sinks are self cooled and conservatively rated for continuous duty at the motor 1 hour rating. Forced air cooling is used with the larger horsepower drives.

Tachometer - A rugged, permanent magnet, high power DC tachometer is used for speed feedback.

Drive Motor - The A500 system is usable with standard intermittant rated wound rotor type motors. Permanent slip resistance is furnished as standard. Starting torque is determined by rotor resistance only since thyristor drop at full gating is approximately 1 volt.

General Application Notes

The Westinghouse 22-A500 thyristor AC control system does not use reversing or accelerating contactors and provides positive sub-synchronous speeds when required for all span load conditions. This AC system provides safe, positive, uniform and smooth accelerating and retarding characteristics as well as uniform pre-determined speeds for seating regardless of span load. A permanent slip resistor section in the motor secondary circuit is designed to limit the breakaway torque.

A span motor feeder contactor is the only contactor used and during span operation will open in case of power failure, emergency stop, undervoltage or motor overload. No accelerating contactors are used. Accelerating and retarding rates are pre-adjusted to the desired value by using a static ramp function generator. Controller adjustment, electrical and mechanical maintenance are kept to a minimum by the elimination of reversing and accelerating contactors, operating the feeder contactor only once for each bridge opening cycle, the use of low voltage control circuits, automatic retardation to a positive low speed before setting of the span motor brakes, stepped and adjusted cushion setting of the brakes to keep the machinery stresses within pre-determined values under the worst conditions of stopping in case of power failure or other abnormal conditions indicated above.

Maximum safety and minimum shock to the span and the drive are provided by interlocking of operating sequence, automatic instantaneous overload, undervoltage relays, automatic and predetermined rate of acceleration and retardation, automatic normal stop at pre-determined position of the span, manual optional normal stop by operator at any time by returning the control switch to off and emergency stop at any time by depressing the emergency stop button.

The thyristor control system provides breakaway, accelerating, retarding, and stable sub-synchronous speed torque characteristics. These points do not involve any switching of either primary or secondary motor circuits, merely the adjustment of thyristor gating. The ramp function generator provides the ultimate in smoothness of operation, and therefore is ideal to reduce the mechanical and electrical stresses. Hence, maintenance is kept to a minimum. The ramp function generator is normally set for 10 seconds acceleration and deceleration.

Types of Control

Automatic Acceleration and Deceleration -- With this method of control, the operator initiates the span motion and the opening or closing of the span continues automatically until either the fully open or fully closed point is reached. The operator can stop the span at any point, but he has no control over span speed. In the normal operation of this type of control, the operator will initiate "bridge open" and the span will start to move in the open direction, accelerating to full speed under the control of the ramp function generator, and continue at full speed until the nearly open position is reached. At this point a limit switch will initiate a slowdown and the span will decelerate under the control of the ramp function generator to a predetermined low speed and continue at low speed until the fully open position is reached and the drive stops and sets the brakes. When "bridge close" is initiated, a similar operational sequence is followed in the close direction. With this type of control, polarity of input signal into the speed controller determines direction of motion and amplitude of input signal determines speed of motion. Usually two amplitude steps are provided, slow speed and full speed. Additional steps of amplitude can be provided, such as a half speed point for use in case of high winds.

Stepped Speed Under Control of Operator -- If it is desired to have the operator control the speed of the span at all times, a master switch can be provided. This switch will give a maximum of six steps in either direction with an off point in the center of travel. The farther away from the off point the operator moves the master switch, the faster the span will move. With this type of control provision is normally made to limit the operator to low speed at certain positions of the span travel, such as between nearly open and fully open positions. The usual method of limiting the operator is to automatically shut down the drive at the slow down point and require the operator to reset the drive by moving the master switch to off and then proceeding at low speed by holding down an auxiliary control such as a foot switch. If the operator attempts to drive the span too fast, the drive will automatically shut down and must be reset. With this method of operation, polarity of reference signal into the speed controller determines direction of motion and the amplitude of the reference signal determines the speed of motion. Usually six steps of amplitude are provided in each direction and only the lower three speeds are usable at the slow down points.

Stepless Speed under Control of the Operator -- If a potentiometer is mounted on the end of the master switch, a variable, stepless input signal can be provided to control speed. Otherwise operation is the same as with the stepped speed control described above.

Troubleshooting

Main Circuits - If motor torque appears lower than normal, check rotor circuit wiring for completeness and agreement with resistor taps as shown in the schematic diagram. Check gate connections to all thyristors. Check maximum regulator output.

Phase Loss Relay 86Y - With power on relay 86Y is energized. Check for circuit breakers being tripped or for reverse or lost phase voltage from the gate control transformer.

Speed Control - Drive speed should be dependant on limit switch position and acceleration control (output of RFG) and independant of load. If drive is not functioning, make these checks: Power on, span control switch in off. Power supply +24 VDC between terminals 35-31, -24 VDC between terminals 55-31, +15 VDC between terminals 33-31 and -15 VDC between terminals 59-31. Output from ramp function generator should be zero volts. With controls set for full speed, RFG output should be + 10 VDC and all gates full on.

DC Power Supply - AC Power requirements: six phase sinusoidal voltages @ 17.5 volts RMS, 75 VA max. Phase sequence requirements - The six voltages are 60 degrees displaced with V_{43-31} leading V_{49-31} leading V_{39-31} leading V_{47-31} leading V_{41-31} leading V_{45-31}.

Outputs -	Non-regulated	PSP	+24 VDC @ 1 amp. Max.	PSN	-24 VDC @ 1 amp. max.
	Regulated		+15 VDC @ 300 ma. max.		-15 VDC @ 300 ma. max.

See IL 16-800-225 in Reference Leaflet Section for details of operation.

Speed Controller - The speed controller mixes the reference signal with the pilot generator signal to provide a control signal to the gate pulse generator and the reverse pulser. See IL 16-800-224 in Reference Leaflet Section for details of operation.

Gate Pulse Generator - The gate pulse generator supplies the signals for firing of the forward or reverse pulsers. See IL 16-800-221 in Reference Leaflet Section for details of operation.

Forward Pulser - The forward pulser controls firing of the open thyristors. Six output pulse trains suitable for firing the thyristors are generated between color coded terminals (brown, red, green, yellow, white, blue) to PSC. Isolation is achieved by pulse transformer networks, S#1562A91G01, mounted externally on the TPM. It also supplies a gate pulse suppression signal to the reverse pulser when required. See IL 16-800-222 in Reference Leaflet Section for details of operation.

Reverse Pulser - The reverse pulser controls the firing of the close thyristors. Four output pulse trains suitable for firing the thyristors are generated between color coded terminals (brown, red, yellow, and green) to PSC. Isolation is achieved by pulse transformer networks, S#1526A91G01, mounted externally on the TPM. See IL 16-800-223 in Reference Leaflet Section for details of operation.

Ramp Function Generator - The ramp function generator (RFG) produces a linear ramp output when the input is a step voltage. Terminals 29 and 59 provide bidirectional opposite polarity ramp signals. With acceleration and deceleration voltage limits applied to terminals 49 and 47 and the input step signal applied, the output signal will ramp linearly until the maximum output of +11 VDC is reached Ramp times are determined by external adjustments of the voltage dividers connected to terminals 49 and 47 and by adjustment of potentiometer 6P.

Voltage Sensing Detector - The voltage detector board is an electronic package containing one or two identical circuits capable of detecting a specified level and polarity of voltage. The voltage detection level and polarity are established by the size of input resistors and the polarity of an externally applied reference voltage respectively. The detector circuit is terminated in externally mounted relays. The voltage detector will pickup and drop out at approximately one volt.

Pilot Generator - If speed regulation is lost, check for continuity in the pilot generator armature circuit. Pilot generator output voltage should be proportional to speed. If this voltage is not obtained, check the pilot generator. If defective, it should be replaced.

Brake Control - If the brakes do not release, check for mechanical binding and coil excitation when the brake contactor is energized. Check thrustor limits for correct oil level.