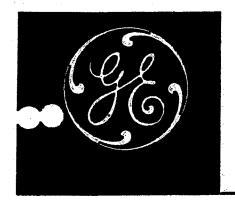
EXHIBIT "A"



AUTOMATIC STATIC CONTROL FOR LOAD-TAP-CHANGER EQUIPMENT

OPERATION OF THE STATIC CONTROL

INTRODUCTION

The control described below incorporates the standard features of voltage sensing, time delay and line drop compensation common to all controls for regulating transformers. All functions except the final output to the motor circuit are performed with static devices in order to minimize the effects of wear over an extended service life. Refer to the control diagram appended.

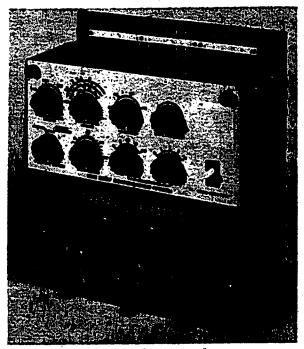
The controls are designed for 60-cycle alternating current operation. All devices are factory-calibrated and adjustments can be made by the calibrated control knobs. No warm up time is required by the controls and the accuracy class is better than Class 1. The control settings can be secured by the locking knobs.

OPERATION

The transformer output voltage is stepped down by a potential transformer and is applied to the input of the control. A test rheostat R24 is provided to permit variation of the voltage applied to the sensing circuit of the control with no change in the transformer output voltage. This facilitates checking of controls at installation.

A 5:1 ratio transformer (T1) is used to reduce the voltage applied to the line drop compensator and sensing circuit. A rheostat (R29) provides for voltage level settings between 105 and 135 volts.

Before being applied to the sensing circuit, the output of transformer (T1) is modified by the line-drop compensator. The line drop compensator consists of a tapped reactor (XLDC) and a rheostat (RLDC) which are used to develop voltages proportional to the IX and IR drops in the line fed by the transformer. The reactor simulates the IX drop and has taps selected to permit the insertion of 0 to 24 volts compensation in one volt steps with rated current flowing in the load current transformer. The resistance compensation is continuously ad-



justable from 0 to 24 volts at rated output current. A compensation polarity selector switch (S1) is provided to permit the reversal of the reactance compensation when required by transformer application. For normal compensation applications the voltage developed across the line drop compensator is subtracted from the transformer output voltage. This forces the transformer output to be higher for a given voltage into the sensing circuit and thus causes the transformer to compensate for the drops created by current flow in the lines.

The voltage sensing element of the control is a zener diode bridge. The legs of the bridge consist of: R6, CR21, CR22, Z1 and R12, CR19, CR20 and Z2, R28, R7 and R15. Resistors R12 and R15 are relatively small and may be ignored in a general analysis of bridge operation. Diodes CR19, CR20, CR21 and CR22 are used for temperature compensa-

These instructions do not perpert to generally details or resisting in popularist our to provide for every possible contingency to be used to generation with installation, operation or minimals. Small further information by desired our should particular problems who which are not covered collected for the purposes, the matter should be related to the General Statute Company.



tion and may also be ignored for general analysis. This leaves the basic elements of the bridge being R6, Z1, Z2, R28 and R7.

The zener diodes serve as reference devices and voltage variations are reflected as differences in voltage across the resistors. Since sener diodes are DC devices, it is necessary to rectify and filter the regulator output before applying it to the sensing bridge. For this application, the bridge is at its balanced condition when the potential at the junction of R6 and CR21 is equal to the potential at terminal point A8. As the applied voltage increases, the potential at A3 rises with respect to the potential at the junction of R6 and CR21. As it decreases the reverse occurs.

The output of the voltage sensing bridge is fed to the control windings of a pair of magnetic amplifiers (AMP1 and AMP2). At balance current flow in the control windings of AMP1 is from R9 to L3 and current flow in the control windings of AMP2 from L3 to R10. Current flow in this direction causes each amplifier to produce negative pulses to the gate circuit of SCR1. Since positive gate voltage is required to make an SCR conduct, there will be no output from the control.

When the applied voltage increases the potential at point A3 rises with respect to the potential at the junction of R6 and CR21. When the increase is sufficient to cause the potential at the lower slider of R28 to go above the potential at the junction of R6 and CR21, the current in the control winding of AMP32 will reverse. This ourrent reversal will cause AMP2 to produce positive pulses to the gate circuit of SCR1 and make it conduct.

It may be seen that the rectifiers CR9 and CR10 in the circuit of AMP2 will force it to function on the half cycle of the AC wave when the bottom of transformer T2 is positive with respect to the top. Therefore, positive pulses from AMP2 cause SCR1 to conduct on the half cycle which applies voltage to the lower portion of the circuit and charges capacitor C4. This potential is applied through CR14 to the time delay circuit which consists basically of a unijunction transistor (UJT1) and an RC charging network (R25 and C5). When C5 has charged sufficiently to cause UJT1 to conduct, the pulse created by this conduction is applied to the gate circuit of SCR2 causing it to conduct. Conduction of SCR2 energizes relay K2 which in turn energizes the lowering output relay K4.

A similar sequence may be followed through when the applied voltage decreases. In this case, the current through the control windings of AMPI reverses when the potential at the upper slider of R28 falls below the potential at the junction of R6 and CR21. Note that the setting of R28 determines the amount of deviation from balance required to initiate a controlling action. Therefore, R28 is the bandwidth adjustment.

Since AMP1 functions when the top of T2 is positive with respect to the bottom, SCR1 is caused to conduct on the half cycle which energizes the upper portion of the circuit. The same timing circuit is energized, but this time through rectifier CR13. Under these conditions, when SCR2 conducts, it will energize relay K1 which will in turn energize raise output relay K3. Note that variable resistor R25 changes the time constant of the RC charging network and is therefore the time delay adjustment element. Since a single timing network is used, a single adjustment provides for equal time delay in either direction.

If the voltage sensing device returns to a balanced condition before capacitor C5 is fully charged or time cycle is completed, the capacitor will discharge thru the same path as the charging network.

In order to facilitate checking the control, a pair of indicator lights is provided to show when the edge of the band has been reached. To keep from unduly loading the circuit during normal operation and to extend lamp life, the circuit is arranged such that the lamps are operative only when the band edge test switch is depressed. These indicator lights may be used to check voltage level and bandwidth but due to circuit loading by the lamps it is necessary that they be off for time delay checks.

Test input terminals are provided on the front of the control to facilitate checking the controls without energising the transformer. To check controls with no voltage on the transformer, connect a variable 120 volt supply to the "test input" terminals, place the selector switch in the "test" position and proceed as outlined under "checking the level and bandwidth." Upon completion of tests, return the selector switch to "normal" to reconnect the control to the transformer output supply.

VOLTAGE SENSOR

GENERAL

The voltage sensing device continuously measures the output voltage of the transformer and controls the operation of the motor of the tap changer, thereby maintaining the output voltage within a preset band.

AEP088

VOLTAGE LEVEL

To adjust the voltage level of the control, rotate the adjusting knob marked "Voltage Level." The voltage level is continuously adjustable between 105 and 135 volts with scale markings in 1-Volt increments.

The sensor is set at the factory for 120-volts with 1.5-volts bandwidths.

BANDWIDTH

To adjust the bandwidth of the control, rotate the adjusting knob marked "Bandwidth." The bandwidth dial is calibrated for 1.5, 2.0, 2.5 and 3.0 volts at normal voltage levels between 110 and 130 volts. The desired bandwidth is obtained by the intersection of the voltage level line and bandwidth line.

The bandwidth is usually made equal to one percent of the control potential, plus the percent value of the voltage tap times the normal potential. For example, assume a 120-volt control potential and five-eights percent taps in the equipment winding; then —

 $1\% \times 120$ volts = 1.20 volts $\frac{5}{6}\% \times 120$ volts = 0.75 volts

Bandwidth (total) = 1.95 volts or approximately 2.0 volts.

CHECKING THE LEVEL AND BANDWIDTH

The normal voltage setting of the voltage sensor should be checked first. Normal voltage is the median of the voltages at the points when the "High" and "Low" band edge indicator lights just go on.

To check the normal voltage level, connect an indicating voltmeter to the potential test terminals on the control panel and set the line-drop compensator for zero compensation. The indicating voltmeter will read the equivalent output voltage of the transformer.

With indicating voltmeter connected to the potential test terminals, proceed as follows:

- 1. Set the "Voltage Level" adjusting knob.
- 2. Manually operate the transformer either "Raise" or "Lower" until the voltmeter reads approximately 2-volts above the upper edge of the desired bandwidth.
- 3. Push the band edge test switch. At this point the "High" light should be lit signifying that the voltage is above the upper edge of the bandwidth.
- 4. Turn the test rheostat in until neither light is lit. Continue turning in the test rheostat until the "Low" light is lit and record the voltage at which

the light comes on. This is the lower edge of the bandwidth.

- 5. Turn the test rheostat in the opposite direction until the "High" light is lit and record the voltage at which this light comes on. This is the upper edge of the bandwidth.
- 6. The median of these two voltage recordings is the true normal voltage setting of the control. Should this actual setting be slightly different than required, slightly adjust the "Voltage Level" control knob accordingly and repeat the above steps. Bandwidth is the interval between when the "High" and "Low" lights just go on.
- 7. Return the test rheostat to "Auto" position and reset the line-drop compensator to the desired value.

TIME DELAY

GENERAL

The time delay provides for a time delay between the energising of the voltage sensing device and functioning of the load-tap changing equipment. The time delay is continuously adjustable from 10 through 90 seconds. To adjust the time delay rotate the adjusting knob indicated "Time Delay" to the desired time.

The timer is set for 30 seconds at the factory, and this is the recommended setting unless particular applications indicate otherwise.

Charging time of the capacitor depends on the length of time the timing cycle has been off. The recovery time of the timer is essentially the same as the charging or cycling time, thus the timer has an integrating action until the output relay closes at which time the timer automatically resets to sero time.

CHECKING TIME DELAY

Place the control in a balance condition within the bandwidth. Start of time delay is initiated when the control is instantaneously placed out of the bandwidth by use of the level adjust. The time between throwing the control out of the bandwidth and when the motor energizes is the time delay.

LINE-DROP COMPENSATOR

The Line-Drop Compensator has adjustable positive resistance and reactance elements in the control circuit which make it possible to simulate actual line impedance. The reactance setting consists of coarse and fine adjustment knobs. A combination of these adjustments provides a range of 0 to 24 volts in one volt steps. A separate switch is provided to permit reversing the reactance compensation for the reverse reactance method of paralleling. A separate reactance method of paralleling.

ance transformer (XTR) is provided to permit parallel operation using the circulating current method. On units where the paralleling control is provided, the individual-parallel selector switch (43TP) is mounted on the control panel.

A line current transformer inside the transformer causes a proportional current to flow through the R and X of the compensator circuit. An auxiliary isolating transformer, (RT) is provided in the control to permit grounding of the line current transformer secondary. The compensator IZ drop is subtracted from the potential transformer secondary voltage, and the resultant is applied to the voltage sensor. This sensor causes the transformer to hold a voltage high enough (or low enough) to compensate for the voltage drop (or rise) to some predetermined location on the line, thus causing the voltage at this point to remain essentially constant. The settings of the line-drop compensator are calculated using the following equations:

R setting (volts) -

lcT* x resistance of the line (ohms)
Potential transformer ratio

X setting (volts) -

Potential transformer ratio

*lcT - Current transformer primary current rating.

Resistance and reactance figures may be obtained from Table I.

For single-phase (2-wire) circuits, double the line R and X values as the total impedance out and back must be factored. If the circuit consists of one line and a grounded neutral, the total will be 1.67 times the R and X values. For three-phase circuits the loads are considered balanced, and the impedance for one wire only need be considered. If the ratio of the potential transformer represents the line to line control potential ratio, divide the ratio by 1.73 to obtain the necessary line to neutral relationship for use with the formulas.

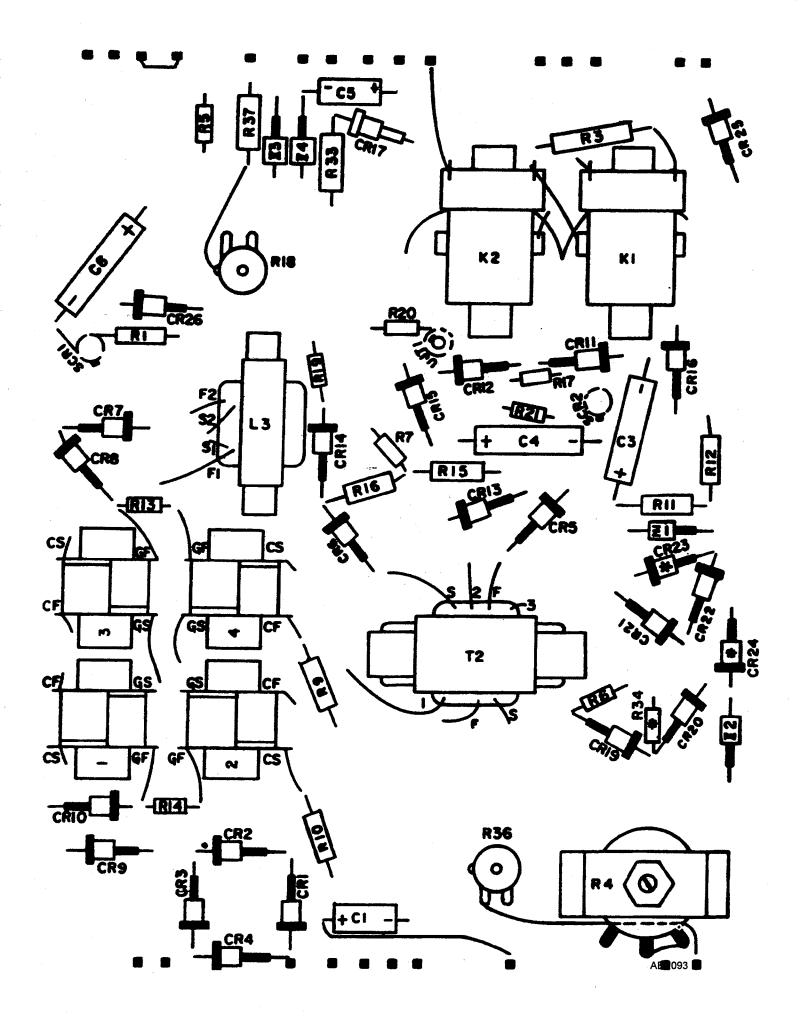
TABLE	ÖF	RESIST	ANCE	AND	REA	CTA	NCE
-------	----	--------	------	-----	-----	-----	-----

		·	RES SOL	STANCE FLE CONE	AND REA	NCTANCE M OHMS	OF OPE PER 100	WIRE O FEST	CIRCUITS AT 60 CY	PER CLES			
					COF	PER—HA	RD DRA	Wee					
WARE	RESISTANCE AT 25C				8			(OHMS		roes*			
	= -	18"	24"	30"	34"	42"	48"	34"	60-	6'	1.8	14'	20'
AWG					T			 	 	 	+	 	
,	.654	.135	.142	.147	.151	.155	.158	.161	.143	į.	1	I .	
•	A13	.136	.137	.142	.146	.150	.153	.156	.158	l	i	l	i
4	.363	.124	.130	.135	.140	.143	.146	.149	.151	i	1	1	
2	.167	.119	.125	.130	.135	.128	.141	.144	.146	ľ	1		ł
	.132	.115	.122	.127	.132	.135	.138	.141	.143	l		l	Į.
1/0	.105	.113	.120	.125	.129	.132	.136	.138	.141	.145	.151	.165	.169
2/0	.083	.110	.117	.122	.127	.130	.133	.136	.136	.142	.149	.162	.166
3/0	.066	.108	.114	.119	.124	.127	.130	.133	.135	.139	.146	.159	.143
4/0 MCM	.053	.105	.111	.116	.121	.124	.127	.130	.132	.136	.143	.156	.160
250	.045	.103	.108	.112	.118	.121	.124	.127	.129	.133	.140	.152	.157
300	.037	.098	.106	.111	.115	.119	.122	.125	.127	.131	.138	.151	.155
350	.032	.094	.104	.109	.113	.117	.120	.123	.125	.129	.134	.149	.153
500	.023	.095	.101	.107	.111	.114	.117	.120	.123	.126	.133	.146	.150
750	.014	.092	.078	.103	.107	.111	.114	.117	.119	.123	.130	.143	.147
1000	.012	.086	.093	.100	.104	.108	.111	.114	.116	.120	.127	.140	.144
a total				ALU	MUM	CABLE -	STEEL R	ENFORC	ED.				
AWG	.475	.132											
4	.425	.132	.138 .133	.143	.147	.151	.154	.157	.159]		
2	367	.122	.129	.138 .134	.142	.146	.149	.152	.154				
1/0	.149	.112	.125	.130	.138 .134	.142	.145	.148	.150				
2/0	.134	.116	.123	.128	.132	.138	.141	.144	.146	.150	.157	.170	.178
3/0	.106	.114	.121	.126	.130	.136 .134	.139	.142	.144	.148	.155	.168	.176
4/0	.004	.112	.119	.124	.128	.134	.137 .135	.140	.142	.146	.153	.166	.174
MCM					20	.132	.135	.138	.146	.144	.151	.164	.172
226.8	.066	.078	.104	.109	.112	.117	.120			• • • •	I I		
336.4	.053	.094	.101	.106	.110	.114	.117	.123	.125	.129	.136	.149	.157
397.5	.045	.093	.099	.105	.109	.112	.115	.120	.122	-126	.133	-146	.154
477.0	.037	.091	.097	.102	.104	.110	.113	.116	.120 .118	.125	.191	.144	.152
556.5	.032	.089	.096	.101	.105	.108	.112	.114	.117	.122	.129	.143	.150
795.0	.022	.085	.092	.097	.101	.105	.108	.110	.113	.127	.127	.140	.148
754.0	.019	.084	.010	.095	.099	.103	.104	.108	.111	.115	.124	.136	.144
272.0	.014	.079	.084	.091	.005	.099	.102	105	107		.121	.134	.142

^{*} THE ROOT AVERAGE OF THE DISTANCE BETWEEN CENTERS OF CONDUCTORS

CAUSE REMEDY	1. Using an AC voltmeter check for cantrol sensing voltage at the voltage test terminals, sauto- is defective. Check for sensing voltage between N1 and N6. If no voltage appears at these terminals, the problem is outside the controls. If voltage does appear at this point, check for faulty "normal-test" power supply switch or a faulty circuit breaker or a faulty test rheostat.	2. Loss of sensing voltage to 2. & 3. Check sensing circuits and relay voltage supply circuits as follows: Push the band-the bridge recilifier or the edge test switch observing the band edge indicator lights, with 120 volts supplied to the zener bridge which are localized from either the internal regulator supply or from an external source connected to cated on the component the terminal marked "Test input" and power supply switch to position marked "Test."	3. Defective relay voltage by use of the level adjustment in and out of the bandwidth both above and below 120 volts supply. Supply to the relay is correct. If not, problem lies in these circuits. Elimination of level adjust theostat would isolate the problem to the component board. This may be accomplished by disconnecting the "X8" (9 point connector) plug assembly between the component board and the panel.	CAUTION: Turn off power before disconnecting plug assemblies.	With an analyzer check the level adjust rheastat R29 for a range of 0.425 ahms ±10%. Also check continuity between panel ground and rheastat terminals to make sure terminals are not grounded. Replace rheastat if defective. If rheastat agrees with correct range and ground test, sensing circuits located on board are defective. Replace companent board.	4. Defective Time Delay Cir. plate the ground circuit does not function, the silicon rectifier SCR 2 will not conduct and comcult. cuit. level adjust test as above except discornect the "XA" (12 point connector) plug assembly. The range will be from 0 to 2.5 megohms ±10%. Replace rheastat if defective. If rheastat is normal, problem will be focated on the board assembly. Replace component board.
TROUBLE	1. Transformer functions 1. manually but not auto- matically in either the raise or lower direction.	N ∓ Ñ J.Ď	en a			4.0

TROUBLE	CAUSE	REMEDY
II. Transformer runs to maximum Raise or max- imum Lower limit.	1. Defective Relays or Sens- ing Circults.	1. If sensing circuits are functioning properly, check for sticking relays. Replace relays, if defective. Caution should be taken when relays are removed from the board. All connections from the relay to the board should be disconnected at the relay and not the board.
iii. brorrect level or Control carnot be bal- anced.	1. Defective Sensing Circuits	1. Check clruits as in I above.
1V. Transformer operates frequently.	1. Incorrect bandwidth.	1. Check bandwidth setting by using band edge indicators and an A.C. voltmeter at the voltage test terminats. See bandwidth check in control settings under "Operation of Static Control," page 1. To check the band rheostat, disconnect power, then disconnect the "XB" plug (9 point connector). With an analyzer check the resistance of each layer of the bandwidth rheostat R2B. Each layer should be 25 chms ±5%. Also check for shorting between the panel ground and terminals of each layer. Replace bandwidth rheostat, if theostat is normal, replace the component board.
	2. Time Delay setting is too low or the circuits are mal- functioning.	2. Place the control in a balanced condition within the bandwidth. Start of time delay is britisted when the control is instantaneously placed out of the bandwidth either by use of the level adjust or the test rheastat.
		The time between throwing the control out of the bandwidth and when the motor energizes is the time delay. If this is drastically different (±20%) from the calibrated setting, the time delay circuit is malfunctioning. Remove component board and return for replacement.
V. Transformer bucks when load increpses.	1. Reversed polarity in either the current transformer or potential transformer.	1. Reverse feads at potential transformer.
Vi. Une Drop Compensator is not functioning in either reactance or	1. S1, S2, or S3 is defective.	1. Check each switch for corrosion or mechanical defects. If defects exist, replace the particular switch. Switching to all positions on each switch would aid in determining fault.
restatance or both.	2. Defective Rheostat RLDC.	2. With the unit deenergized and "XB" connector disconnected, measure the resistance between the side arm and N10. Vary the rheostat from one extreme to the other, a variation of 24 ohms ±1% should be noted. If not, rheostat is defective and should be replaced.
ΛE	3. Defective Current Trans- former.	3. If all components in 1, and 2 are normal, but no compensation exists, a defective current transformer is the probable cause.
2002	4. Factory installed short circuit on current supply.	4. A terminal board may be installed by the factory to short circuit the LDC current transformer. This jumper should be removed when the transformer is placed in service, check CT witing for removal of this jumper.



POWER TRANSFORMER DEPARTMENT

GENERAL ELECTRIC

PITTSFIELD, MASS.