# Chapter 10

# LABINAL GENERATING SYSTEM

## LIST OF CONTENTS



## LIST OF ILLUSTRATIONS



## LEADING PARTICULARS

| | |
|---|---|
| *Output voltage* | 200*V*, 3-*phase*, $\pm 2\frac{1}{2}$ *per cent.* |
| *Frequency* | 400 *c/s* $\pm 1\frac{1}{2}$ *per cent.* |
| *Power factor* | 0·8 *lag to unity* |
| *Max. continuous load* | 4 *kVA.* |
| *Input speed range* | 2900–8000 *rev/min.* |
| *Components:—* | |
| *Plessey two-speed gearbox* | *Ref. No.* 5*UA*/7184 |
| *Generator Type* 165 | *Ref. No.* 5*UA*/7183 |
| *Control panel, Type* 46. (*Voltage regulator*) | *Ref. No.* 5*UC*/6926 |
| *Control panel, Type* 47. (*Frequency regulator*) | *Ref. No.* 5*UC*/6927 |
| *Control panel, Type* 48, *No.* 2. (*Speed sensing unit*) | *Ref. No.* 5*UC*/7307 |
| *Protection control unit, Type A* | *Ref. No.* 5*UC*/7619 |

## APPENDICES

## Introduction

**1.** The system is designed to supply power at a constant frequency and voltage over a wide range of input drive speeds. An automatic two speed gear box mounted between engine drive and constant speed generator assembly, provides an extended input speed range. The gear box is operated at predetermined speeds and controlled by the speed sensing unit. Voltage regulation is obtained by control of the generator field excitation current. Frequency regulation is obtained by controlling the excitation current to the eddy current brake of the generator constant speed unit. A protection control is provided in the system, and is designed to automatically connect the generator to the aircraft busbar and to provide protection against, undervoltage, overvoltage and under frequency faults.

# DESCRIPTION

## Two-speed gearbox

**2.** The two-speed gearbox comprises a triple planet assembly, the planet carrier and planet assemblies being free to float about the input and output sun gears. Drive to the planet carrier is achieved by a form of cam and roller clutch, the locked or drive position being reached when the carrier speed attempts to exceed the input drive speed. With the carrier locked by the solenoid operated brake unit to give the step-up ratio, the override cam and roller clutch runs completely free.

**3.** The mode of operation is that of compound spur, the step-up ratio being 1·62:1 for input speeds between 1500 and 5050 rev/min. Below and above these speeds the disengagement of the solenoid operated brake results in the unit reverting to direct drive.

**4.** The automatic gear change point is achieved by the use of the output frequency from a generator which is fitted into the gearbox housing at the drive end, the rotor being fitted directly to the drive shaft. The output signal is supplied to the speed sensing unit, which controls the selected points in the engine speed range at which the change occurs.

**5.** Under conditions of no output from the generator, it would be possible for the gearbox to remain in the engaged state after the brake has become de-energized; this is a function of the reaction torque at the output shaft, a value in the region of 10 oz. in. being necessary to accelerate the planet carrier under all engine acceleration conditions. An accelerating clutch is built into the assembly, between the planet carrier and the output shaft, thus ensuring that the carrier is always driven at the output shaft speed when the brake is de-energized.

## Speed sensing unit

**6.** The speed sensing unit is designed to operate the two speed gearbox, at the predetermined speeds. The unit contains two circuits, both fed from two separate secondary windings of a transformer T1. The primary side of T1 is connected to a generator, which together with a solenoid clutch, forms a part of the two speed gearbox.

**7.** Circuit (a) is the clutch control circuit, and operates the clutch solenoid. Circuit (b) is the overspeed protection circuit and de-energizes the clutch solenoid at speeds above 5300 rev/min and re-energizes at 4950 rev/min.

### *Clutch control circuit*

**8.** The circuit consists of double section low pass filter network comprising inductors L1 and L2, and capacitors C1A, C1B, C3, C4 and C5 which functions as a frequency sensing circuit. The output from this circuit is applied to the solenoid switching circuit comprising resistors R1 and R2, rectifier MR1, capacitor C6, Zener diodes Z2, thermistor TH1, and transistor VT1. The emitter and collector connections of transistor VT1 are connected respectively to the 28V d.c. supply and to the solenoid clutch coil in the two-speed gearbox.

### *Overspeed protection circuit*

**9.** If the input speed exceeds 5300 rev/min and clutch control fails to switch off, the overspeed protection unit is designed to ensure that the gearbox reverts to the 1:1 ratio. The circuit consists of a single section high pass filter network comprising inductor L3 and capacitors C7, C8 and C9 which functions as a frequency sensing circuit. The output from this circuit is applied to the switching circuit comprising resistors R4 and R5, rectifiers MR2/1, MR2/2 and MR3, capacitor C10, Zener diode Z1, thermistor TH1 and transistor VT2.

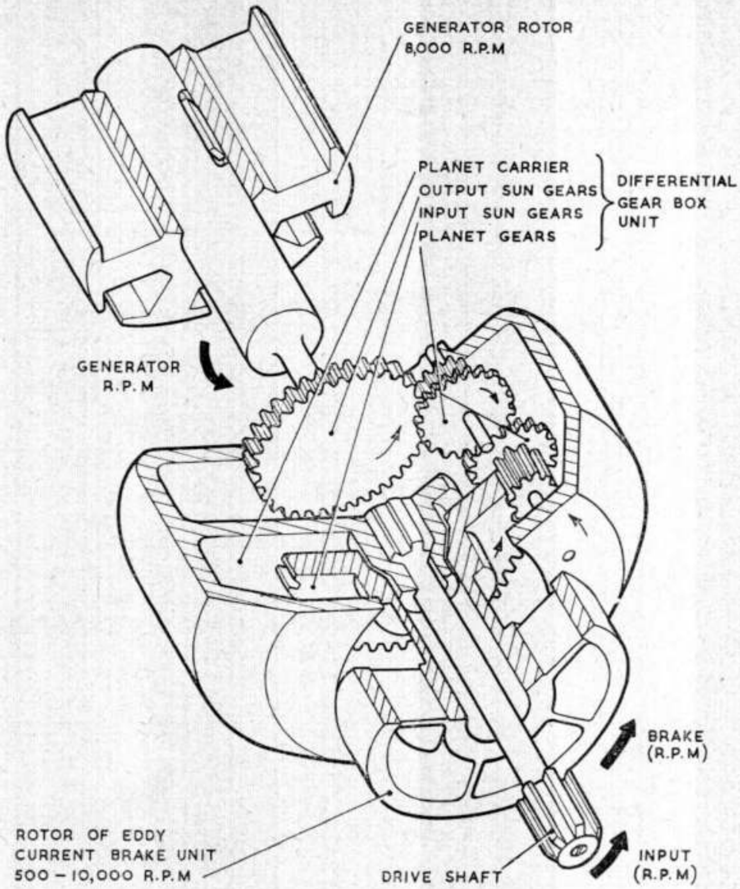


**Fig. 1. Pictorial view of generator and constant speed unit**

**Generator**

**10.** The generator and constant speed unit are complete as one assembly, the constant speed unit being coupled on one side to the variable speed input drive, and on the other to the generator rotor. Speed regulation of the generator and hence the output frequency is effected by controlling the speed of rotation of an eddy current brake motor. The frequency regulator provides an excitation current to the brake such that a momentary increase in frequency corresponds to a decrease in excitation current, and a decrease in frequency causes an increase in excitation current.

*Constant speed unit*

**11.** The constant speed unit consists of an eddy current brake coupled to one of the sun gears of a differential gearbox, the other sun gear driving the generator rotor. The planet carrier is driven by the variable speed input shaft.

*Eddy current brake*

**12.** The eddy current brake comprises a 4-pole d.c. excited stator unit, and a soft iron squirrel cage rotor into which eddy currents are induced to produce a braking torque.

*Differential unit*

**13.** The differential unit is of the compound epicyclic type, having a two wheel planet assembly. The planet carrier housing is connected to the variable speed input drive by means of a splined shaft, and the input and output sun gears are connected solidly to the brake rotor and the generator rotor respectively.

### Voltage regulator

*Voltage reference circuit*

**14.** The components of the voltage reference circuit consist of a voltage bridge comprising resistors R1, R2, R3, R4, R7 and RV1 and a neon reference valve V. The supply to the voltage reference bridge is from the a.c. busbar through the 3-phase halfwave rectifier MR3, the other side of the bridge is connected to neutral. The output from the bridge is applied to a control winding of the magnetic amplifier MA. Adjustment of the voltage setting is effected by variable resistor RV1.

*Magnetic amplifier*

**15.** The magnetic amplifier consists of a single phase bridge arrangement of rectifier MR2 in series with the amplifier main winding, and supplied from transformer T1. The output of the bridge is applied to the series connected saturation windings of the compounding transformers. The control signal for this output is the output from the voltage reference circuit applied to the first control winding.

**16.** The control circuit is stabilized by the use of a transient feedback signal, derived from the compounding transformer secondary winding, this signal is applied to the second control winding in such a direction as to oppose the system disturbances producing the signal. Adjustment of stability is obtained by means of variable resistor RV2.

*Compounding transformers*

**17.** The compounding transformers TC1, TC2, and TC3 are saturable transformers connected in the generator phase lines. Each transformer has four windings, a current winding and a voltage winding, which form the primary side of the transformer; a secondary winding and a saturation winding. The current winding is connected in series with each of the generator phase lines. The voltage winding is energized by a current proportional to and in quadrature with the load current, this effect being obtained by the insertion of an inductance in series with the winding between the phase and neutral points. The secondary winding output current, which is proportional to the vector sum of the primary current and voltage, is applied through rectifier MR1 to the generator exciter field. Without further saturation of the core the generator voltage is higher than normal, both on open circuit and on load. The saturation winding, the current in which is controlled from the voltage reference bridge network, adjusts the saturation point of the transformer to such a value as to maintain nominal voltage at the a.c. busbars at all times.

**18.** The residual flux in the generator rotor normally produces a build up on starting, but to ensure operation at all times the field is excited from the d.c. supply. The supply is permanently connected from the d.c. busbar through resistor R8 and blocking rectifier MR4 to the generator field, the current flowing is of the order of 0·12A.

### Frequency regulator

*Frequency discriminator circuit*

**19.** The frequency discriminator circuit consists of two single-phase bridge arrangements of rectifiers MR3 and MR4 both supplied through the transformer T2. The circuit containing MR3 is a high pass filter network comprising capacitors C1, C2, C3 and inductor L; the output from this circuit supplies a control winding of the magnetic amplifier MA. The circuit containing MR4 supplies a polarising winding of the magnetic amplifier, and is in opposition to the control winding. Potentiometer RV1 is connected in circuit with the polarising winding to provide adjustment.

*Magnetic amplifier*

**20.** The magnetic amplifier consists of a main winding supplied from transformer T1, the output is rectified by MR2 and applied to the saturation winding of each compounding transformer. The control signal for this output is the output from the discriminator circuit applied to the control winding and polarising winding. A phase advancing network is incorporated which allows the unit to have high gain with good stability control.

*Compounding transformers*

**21.** The compounding transformers TC1, TC2 and TC3 are saturable transformers connected in the generator phase lines. Each transformer has four windings, a current winding and a voltage winding which form the primary side of the transformer, a secondary winding and a saturation winding.

**22.** The arrangement is identical in composition to that of voltage regulator except

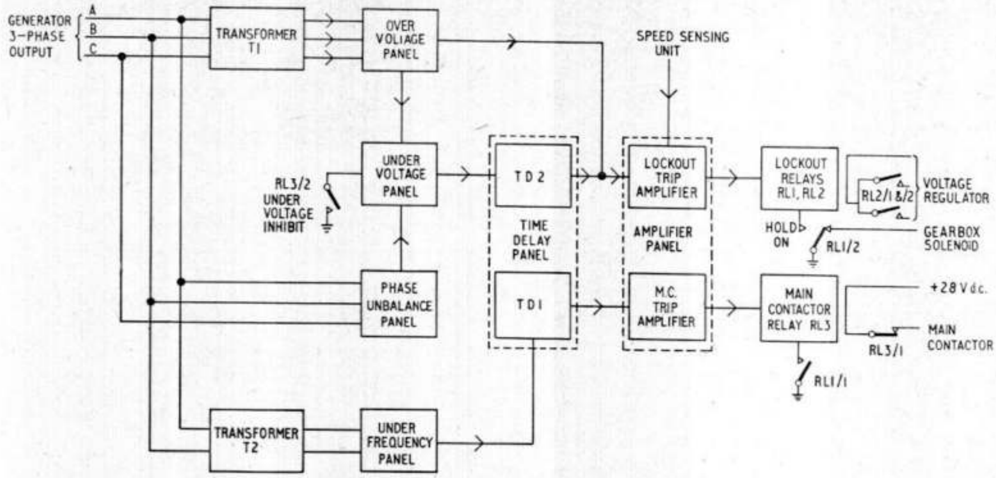


**Fig. 2. Protection control unit schematic diagram**

that the phasing of the primary voltage windings is modified. The secondary winding output current is applied through rectifier MR1 to the stator of the eddy current brake motor.

### Protection control unit

**23.** This unit automatically connects the generator to the aircraft busbars and gives protection against overvoltage, undervoltage, phase unbalance and under-frequency faults. In conjunction with the speed sensing unit, it also provides an overspeed protection.

**24.** The overvoltage, undervoltage, phase-unbalance, under-frequency, time delay and amplifier panels which comprise the unit each consist of a plug in printed circuit board assembly. See schematic diagram fig. 2.

*Function*

**25.** The function of the protection control unit may be divided into two sections;

(1) To control, in conjunction with the under-frequency panel, the supply to the main contactor. When an under-frequency condition obtains, the generator is isolated from the aircraft busbars and is re-connected automatically when the frequency reverts to normal.

(2) To break the supply to the main contactor and to the generator field (in conjunction with the voltage regulator) in the event of over-voltage, over-speeding, under-voltage or phase-unbalance conditions. The system locks out under any of these conditions and the main contactor field remain de-energized until the system is reset by operating an external push button switch. The gearbox solenoid circuit is also broken when the system locks out.

## OPERATION

### Voltage regulation

**26.** The busbar voltage is regulated by the control of generator excitation, dependent upon the load current delivered by the generator and the error between the desired line voltage and the actual line voltage. Field excitation current is provided by the secondary windings of the compounding transformers passing through rectifier MR1. The current in the secondary windings is proportional to the vector sum of the primary current and voltage, this arrangement automatically compensates for variation in the power factor.

**27.** The voltage reference circuit compares the rectified line voltages with a constant voltage obtained at the terminal of the neon reference valve. The voltage difference detected across the bridge network is then applied to the control winding of the magnetic amplifier, and determines the saturation current necessary to adjust the compounding transformers.

**28.** If the voltage difference at the reference point is positive, the increased voltage at the control winding of the amplifier creates an increase in saturation current of the compounding transformers, causing a decrease in the generator excitation current and a resultant decrease in the line voltage. If the voltage difference at the reference point is negative, the opposite of the foregoing occurs and the line voltage is increased.

### Frequency regulation

**29.** The principle of operation of the frequency regulator is similar to that of the voltage regulator. The generator speed, and hence frequency, is regulated by controlling the slip of the eddy current brake motor. Excitation current to the brake motor is provided by the secondary windings of the compounding transformers, rectified by MR1. The output of the secondary windings is dependent upon the load current delivered by the generator and the direction and magnitude of the frequency error. The generator torque is dependent upon its power output, and the brake motor torque is a function of its excitation current, therefore for all values of true power delivered of generator, there is a corresponding excitation current to the brake motor maintaining the two torques in equilibrium.

**30.** The frequency discriminator circuit detects any variation in frequency from the desired value, and operates the control winding of the magnetic amplifier. The output current of the amplifier is supplied to the saturation winding of each compounding transformer, and changes rapidly when the frequency varies from 400c/s.

**31.** If the frequency tends to increase the saturation winding adjusts the compounding transformers so that a decrease in brake motor excitation occurs, resulting in a decrease in generator rotor speed. The inverse occurs if the frequency tends to decrease.

### Protection circuits

*Normal conditions*

**32.** Under normal running conditions, there is no signal at the input to the M.C. trip amplifier; consequently VT7 is cut off, VT8 conducts and VT9 is cut off. The circuit from RL3 to earth via VT9 is thus open and RL3 is de-energized. There is also no signal at the input to the lock-out amplifier, consequently VT10 is cut off, VT11 conducts and VT12 is cut off. The common circuit from RL1 and RL2 to earth via MR34 and VT12 is thus open and RL1 and RL2 are de-energized. The main contactor is energized via RL3/1 and the generator 3-phase output is connected to the aircraft busbars.

*Under-frequency protection*

**33.** The primary winding of transformer T2 connects to phases A and B of the 3-phase supply. The secondary voltage is rectified by the bridge rectifier MR23–26 and the positive d.c. output, which is smoothed by L1, C5, is supplied to the divider R19, R21, MR20 is normally conducting; if the frequency exceeds $375\pm5$c/s, the potential at the junction of R19, R21, is sufficient to cause MR21 to conduct. A proportion of the voltage across RV4 is applied via MR21 and R22 to the base of VT3. VT3 conducts and VT4 is cut off. The positive potential at the collector of VT4 is applied to the input of TD1 via MR22; VT5 conducts, short circuiting C6.

**34.** The circuit comprising R17, T2, L1, C5, and the rectifier MR23–26 is designed to be frequency conscious, and the d.c. output voltage is relatively independant of input voltage over its operational limits. If the frequency falls below the prescribed minimum, this output voltage falls. The potential at the junction of R19, R21, falls so that MR21 no longer conducts. VT3 is switched off and VT4 is switched on, so that the potential at the collector of VT4 falls. The transistor VT5 is normally conducting so that C6 is short-circuited. When VT4 conducts, the positive potential is removed from the base of VT5 and VT5 is cut off. C6 charges through RV7, R27, and, after a time delay determined by the time constant of RV7, R27, C6, the potential across C6 becomes sufficient to cause MR28 and MR27 to conduct. A positive potential is applied via MR28 and MR27 to the input of the M.C. trip amplifier. VT7 conducts, VT8 is cut off and VT9 is switched hard on, completing the circuit of RL3 to earth. RL3 becomes energized, the supply to the main contactor is broken by RL3/1 and the generator is thus isolated from the aircraft busbars.

**35.** When the frequency reverts to normal, the voltage at the junction of R19, R21, rises; VT3 is switched on and VT4 is cut off. The positive voltage at the collector of VT4 is applied to VT5 base via MR22 and R26. VT5 conducts, discharging C6. The M.C. trip amplifier reverts to normal with VT9 cut off. RL3 is de-energized and the generator output is again connected to the aircraft busbars by the main contactor.

*Over-voltage protection*

**36.** The generator 3-phase output is connected via T1 to the full-wave rectifier MR1–3 and MR10–12 on the over-voltage panel. The rectified positive output voltage is applied across the divider R1, RV1, R2, R3. C1 is charged to a level determined by the input voltage and the setting of RV1. MR6 and MR4 are normally conducting; if the input voltage rises sufficiently, C2 charges via RV5 to a potential high enough to cause MR8 to conduct and a positive output is applied via MR8, MR9, to the input of the lock-out trip amplifier. VT10 conducts, VT11 is cut off and VT12 is switched hard on, completing the circuit of RL1 and RL2 to earth via MR34. RL1 and RL2 are energized and both relays are locked on by RL1/2. RL1/1 completes the circuit of RL3 to earth. The system is therefore locked out. All relays remain energized until the circuit is reset by momentarily removing the positive 28V d.c. supply by depressing the reset button external to the unit. It will be apparent that the greater the over-voltage, the more rapidly will C2 charge to the potential necessary for MR8 and MR9 to conduct; the circuit has, therefore, an inverse time/voltage characteristic. When the over-voltage condition no longer obtains, C2 discharges via MR7 and R5.

*Under-voltage protection*

**37.** The positive d.c. voltage from the full wave rectifier in the over-voltage panel is applied to the input of the under-voltage panel. This voltage is smoothed by R6, C3, and is applied to the divider R7, RV2. Normally, the voltage applied to MR17 is sufficient to make MR17 conduct and VT2 is switched on. VT1 is switched off and consequently the positive potential via R10, MR14, R11, holds VT6 hard on; C7 is thus short-circuited. If the input voltage falls sufficiently, VT2 is switched off; VT1 conducts and the positive potential is removed from the base of VT6. C7 charges via RV6, R29, and after a time delay determined by the time constant RV6, R29, C7, the voltage across C7 becomes sufficient to cause MR30 and MR29 to conduct. A positive potential is applied to the input of the lock-out amplifier and the system then locks out as described previously.

**38.** If an under-frequency condition exists, the action of the under-voltage circuit is inhibited as follows. RL3 will be energized and consequently RL3/2 will have changed over so that the potential at the collector of VT2 is held close to earth via MR13 and RL3/2, independent of the state of VT2.

*Phase unbalance protection*

**39.** The three phases are connected to star-connected resistors of equal value, R13, R14, R15, in the phase unbalance panel. If the phase voltages are equal, the junction of the three resistors is a virtual earth and only a small voltage (caused by 3rd harmonic, etc.) is applied to the divider RV3, R16, via MR19; C4 is charged to a low potential. If a sufficient unbalance exists between the phases, the potential across C4, applied via R12, MR18, to the junction of MR15, MR16, becomes great enough to make MR16 conduct. VT1 conducts, VT6 is cut off and C7 charges via RV6, R29. The system locks out as described previously.

**40.** If an under-frequency condition exists, the under-voltage protection circuit is inhibited as previously described. However, the phase-unbalance circuit will still operate, since the inclusion of MR15 allows the base of VT1 to be driven positive via MR18, even when MR13 is earthed via RL3/2.

*Overspeed protection*

**41.** A positive output from the speed sensing unit is applied via R37 to the base of VT12. Under normal conditions, this voltage is insufficient to drive VT12. If an overspeed condition obtains, the output from the speed sensing unit switches VT12 on; RL1 and RL2 are energized and the system locks out.

# Appendix 1

# PROTECTION CONTROL UNIT FOR LABINAL GENERATING SYSTEM PRE-MOD. 239

## LIST OF ILLUSTRATIONS



## LEADING PARTICULARS

| | |
|---|---|
| *Protection control unit Type* 2*Y* | *Ref. No.* 5*UC*/6936 |
| *Supply voltage phase/line* | 3-*phase*, 120/208 *volts.* |
| *Supply frequency* | 400 c/s |
| *Weight* | $2\frac{1}{2}$ *lb.* |

### Introduction

**1.** This appendix deals with Protection Control Unit Type 2Y, which was fitted in Gnat T Mk. 1 aircraft prior to the incorporation of Mod 239. (Protection Control Unit Type A).

## DESCRIPTION

### Protection control unit

*Overvoltage circuit*

**2.** The overvoltage protection circuit comprises a three-phase halfwave rectifier system MR1, a potentiometer network consisting of RV1, R1 and R2, voltage reference diode V1, variable resistor RV2 and relay RL1. The operation of the relay RL1 is retarded by the RC system comprising R3 and C1 in parallel with the relay coil. The voltage level at which the relay operates is adjusted by means of RV1, and variable resistor RV2 in series with RL1 provides a means of adjusting the relay current and hence the time delay of the circuit.

*Undervoltage circuit*

**3.** The undervoltage protection circuit comprises relay RL2, a single phase bridge rectifier MR2, resistors R4, R5, R6, R7 and R8, and variable resistors RV3 and RV4. The relay RL2 has two differential coils (a) and (b). Coil (a) is energized from the average of the three single phase voltages of the rectifier MR1. Coil (b) is connected between the generator neutral and an artificial neutral created by the equal resistors R6, R7 and R8 through the single phase bridge rectifier MR2; the voltage across coil (b) will be proportional to the unbalance of the single phase voltages.

*Under-frequency circuit*

**4.** The underfrequency protective circuit consists of two single phase bridge arrangements of rectifiers MR3 and MR4, both supplied from the auto-transformer TA1, a magnetic amplifier MA and a relay RL3. The circuit containing MR3 is a low pass filter network comprising capacitor C2 and inductor L1, the output of this circuit supplies the control winding of the magnetic amplifier. The circuit containing MR4 supplies the polarising winding of the magnetic amplifier. The connection of the windings is such that the ampere turns produced by both windings are in normal opposition. The supply to the main winding of the magnetic amplifier is through the auto-transformer TR1, the out-put is rectified by MR5 and applied to the coil of relay RL3.

## OPERATION

### Protection circuits

*Overvoltage protection*

**5.** When the average phase voltage exceeds a pre-determined limit, the reference diode V1 strikes, and relay RL1 operates after a time delay of 3 to 5 seconds. When the relay is energized its contacts close to supply 28V d.c. to the coil of relay RL6, relay RL6 operates and its normally made contacts break to open the hold-in circuit of relay RL4, and its normally open contacts close to maintain itself energized and to short circuit the primary windings of voltage regulator compounding transformers, thereby de-energizing the generator field. Relay RL4 opens to remove the supply from the main contactor.

*Undervoltage protection*

6. When the phase voltages are normal, the contacts of relay RL2 are made to supply 28V d.c. to the coil of relay RL5, when any one of the phase voltages drops to approx. 90V, the unbalanced voltage detected by coil (b) produces ampere turns in coil (b) in opposition to that of coil (a), and the contacts change over. The operation of RL2 removes the supply from relay RL5, which changes over after 3 to 5 seconds, the supply being maintained during this time by the discharge of capacitor C4. When relay RL5 changes over the 28V d.c. supply to the coil of RL6 is completed; this circuit is connected through the contacts of RL3 when energized, through the normally made contacts of relay RL2 and relay RL5 through the blocking rectifier MR6 to the coil of relay RL6, Relay RL6 operates and holds in removing the supply to the main contactor and de-energizing the generator field.

*Underfrequency protection*

7. When the frequency is lower than approx. 380c/s the sum of the ampere turns of the magnetic amplifier control and polarising windings, is of a magnitude and polarity such that magnetic circuit is de-saturated. The output voltage will be insufficient to operate or maintain relay RL3, and the relay will remain open, or move from the closed to the open position.

8. When the frequency rises above approx. 380c/s the output voltage to the magnetic amplifier control winding rapidly decreases, the ampere turns at first cancel out, and then polarise the core such that the magnetic circuit is fully saturated; the full operating voltage will then be applied to the coil of relay RL3. When relay RL3 is open the 28V d.c. supply circuit through relay RL2 to the coil of RL5 is interrupted, RL5 opens after a time delay of 3 to 5 seconds and removes the supply to the coil of relay RL4. Relay RL4 opens and removes the supply to the main contactor. When RL3 is closed the opposite of the foregoing occurs. The main contactor then will be opened when the frequency is less than 380c/s and closed when the frequency is greater than 380c/s.



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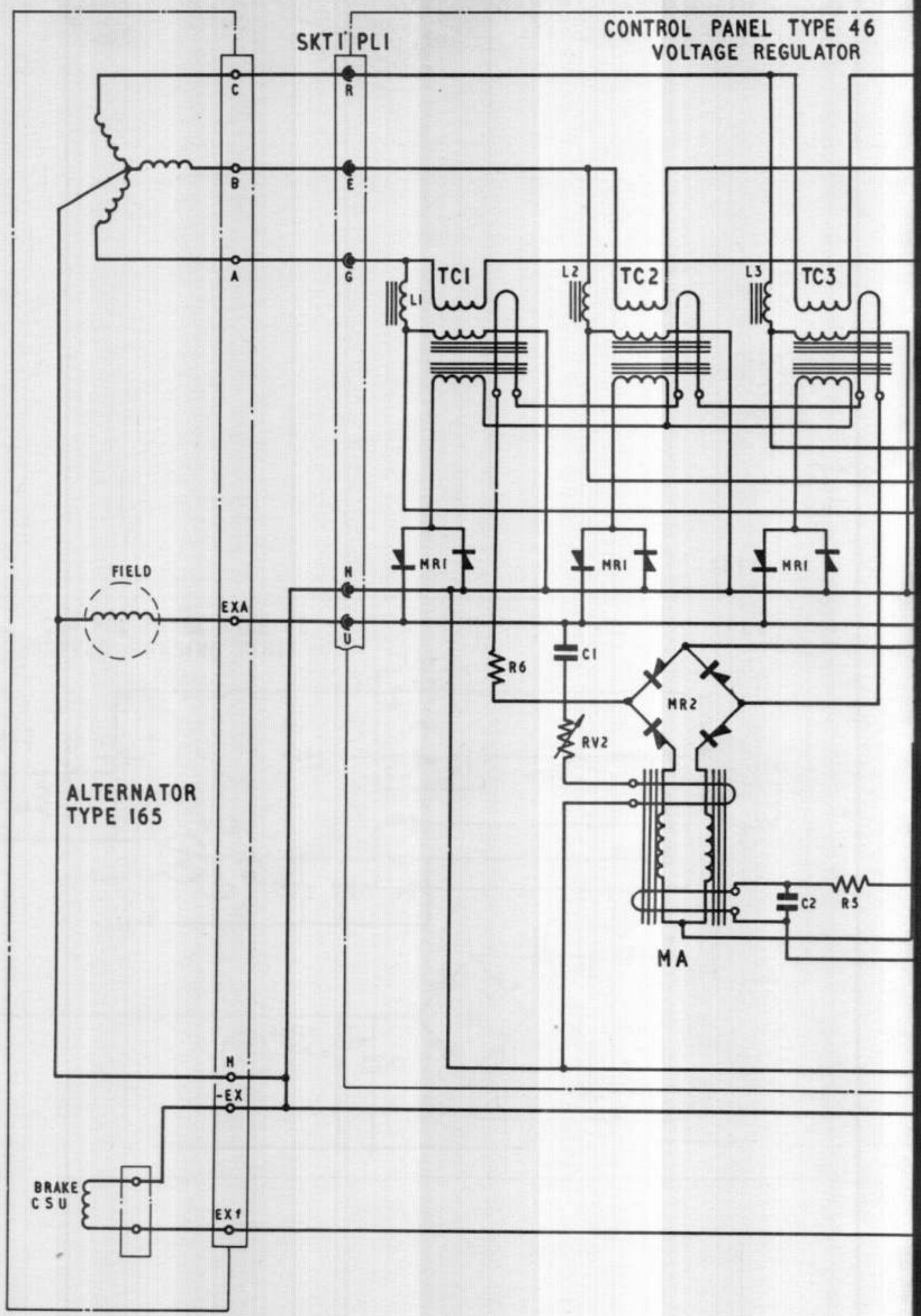
CONTROL PANEL TYPE 46
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C
B
A
R
E
G
N
U
TC1
TC2
TC3
L1
L2
L3
MR1
MR1
MR1
FIELD
EXA
R6
C1
MR2
RV2
ALTERNATOR
TYPE 165
C2
R5
MA
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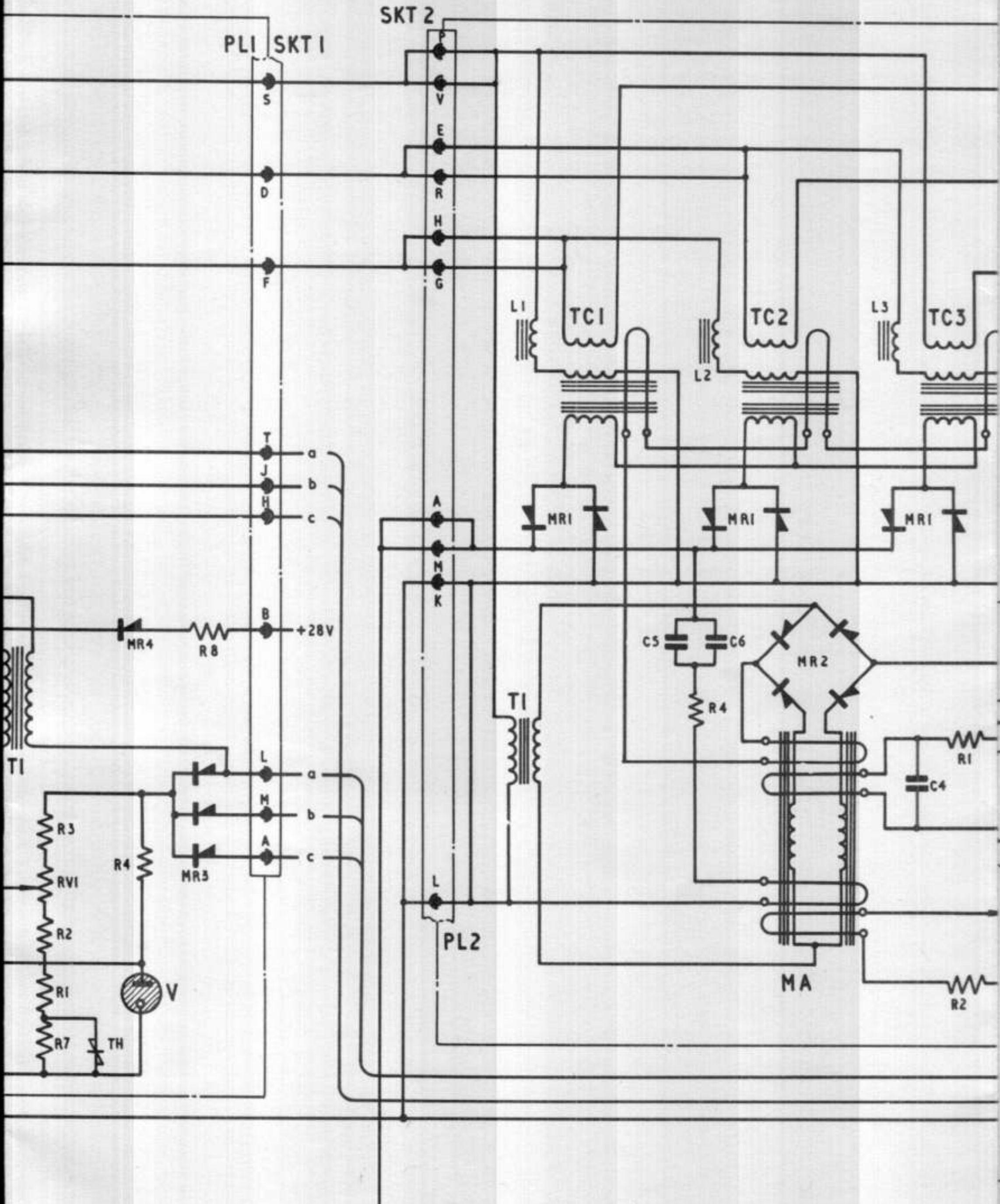
-EX
BRAKE
CSU
EXf
Fig.1



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TC1
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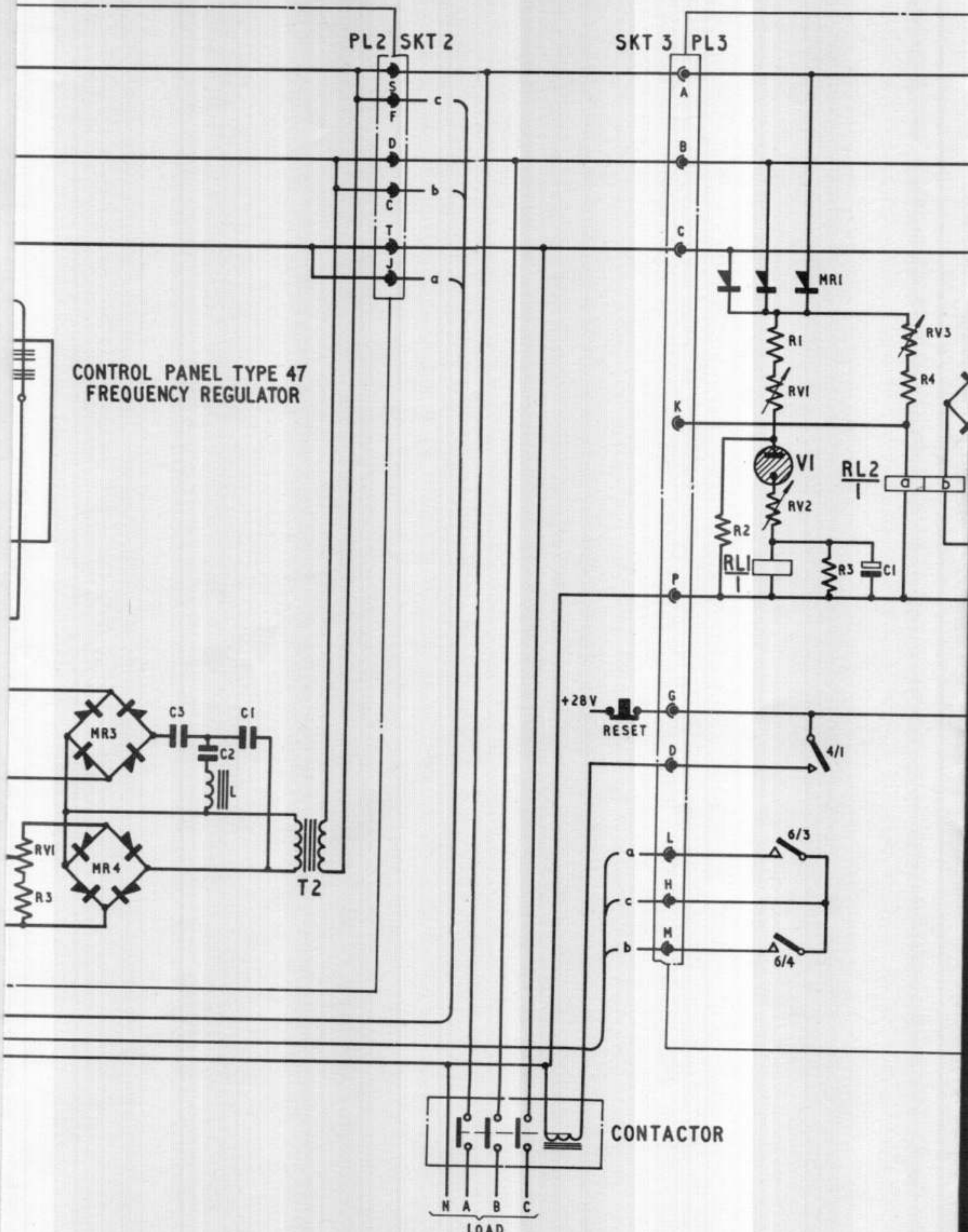
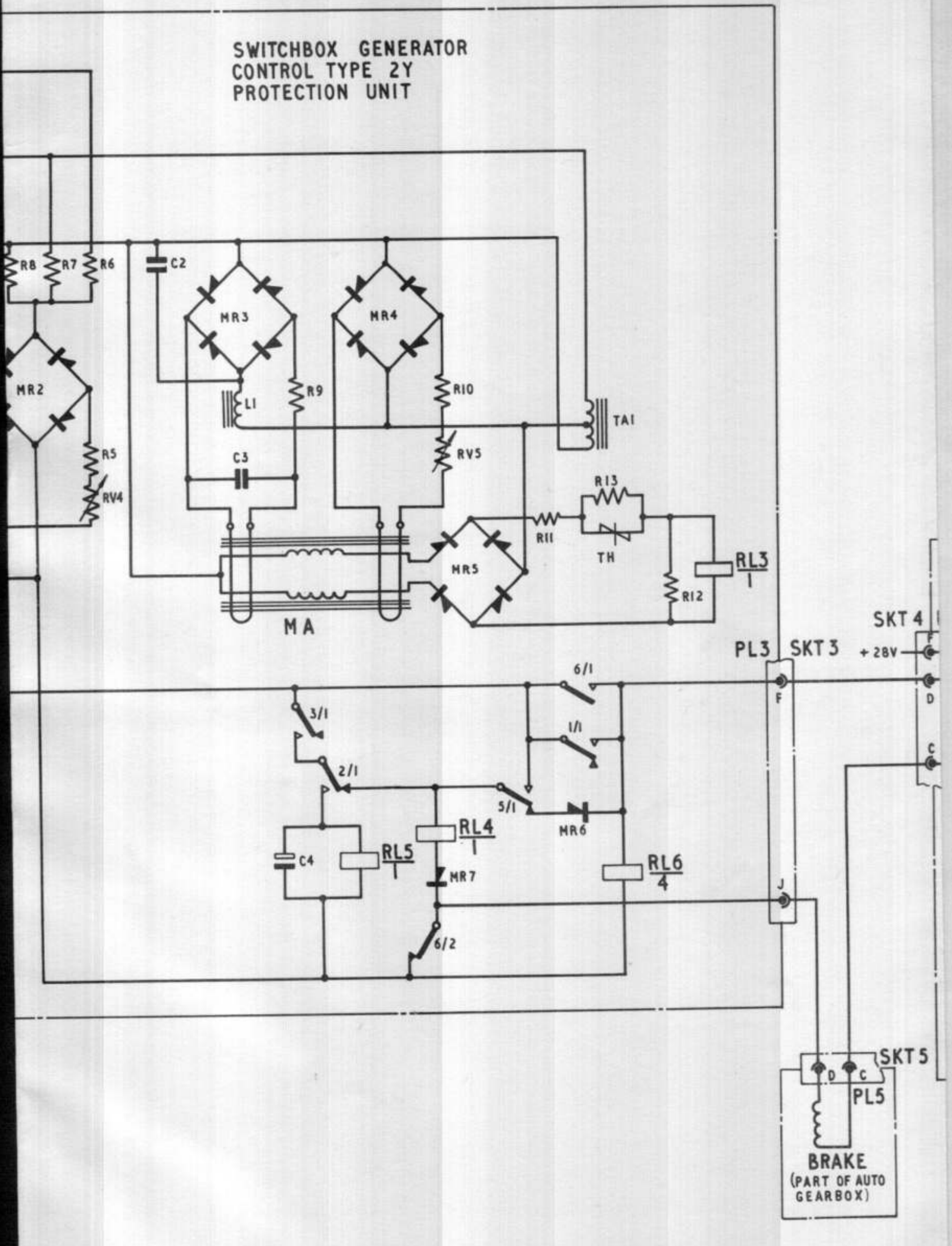



Circuit diagram
RESTRICTED


SWITCHBOX GENERATOR
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R8
R7
R6
C2
MR3
MR4
MR2
L1
R9
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R5
RV4
C3
RV5
R13
R11
TH
MR5
RL3
1
R12
MA
SKT 4
PL3
SKT 3
+ 28V
F
D
6/1
3/1
1/1
C
2/1
5/1
MR6
RL4
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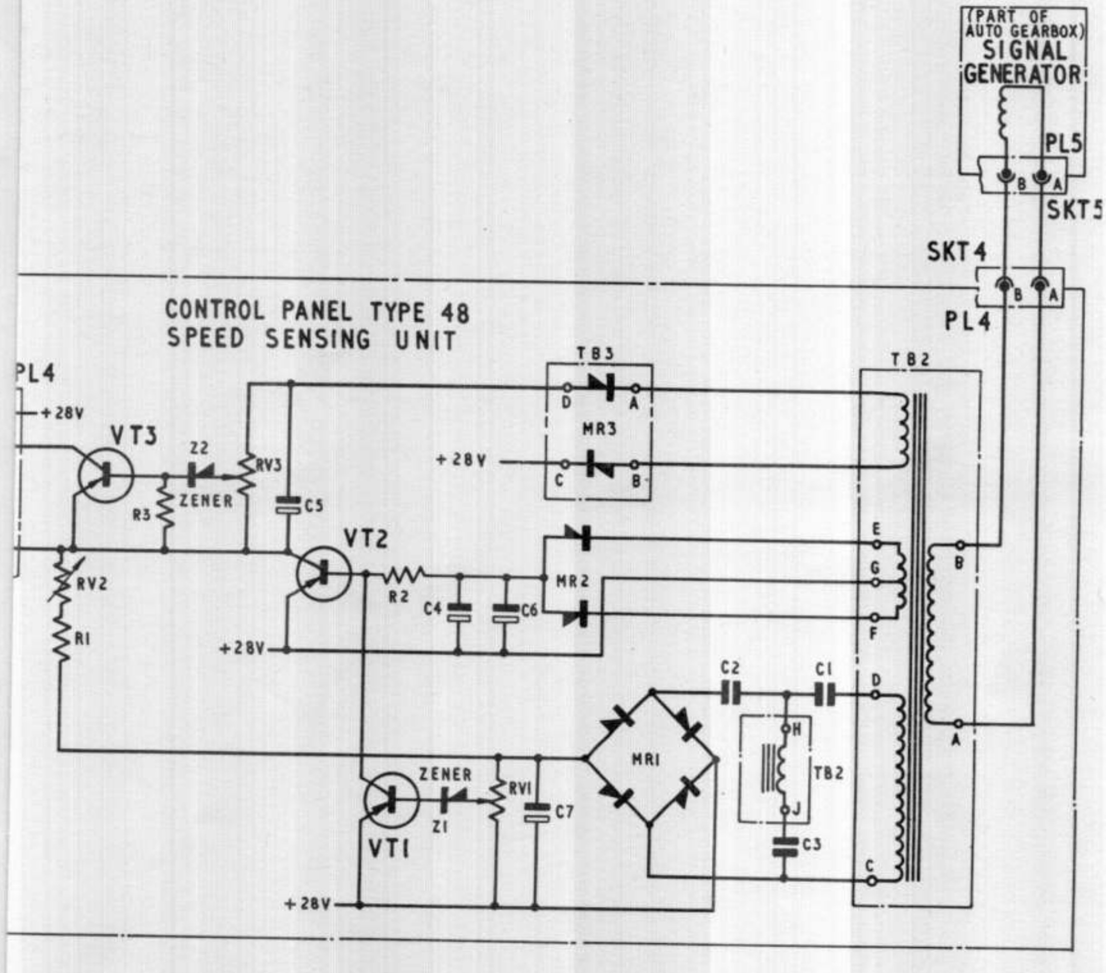
(PART OF AUTO
GEARBOX)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SKT4
PL4
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VT3
Z2
ZENER
RV3
R3
C5
TB3
MR3
+28V
VT2
R2
C4
C6
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RV2
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B
D
A
C
C2
C1
H
J
TB2
C3
MR1
VT1
ZENER
Z1
RV1
C7
+28V

Fig.1