No. 175

The Institution of Post Office Electrical Engineers.

Telephone Exchange Power Plant Development Trends & War-time Problems

W. J. MARSHALL

A Paper read before the Harrogate Sub-Centre on the 12th December, 1941, and at other Centres during the Session.

No. 175

The Institution of Post Office Electrical Engineers

Telephone Exchange Power Plant Development Trends and War-time Problems

W. J. MARSHALL

A Paper read before the Harrogate Sub-Centre on the 12th December, 1941, and at other Centres during the Session.

Telephone Exchange Power Plant Development Trends and War-time Problems

INTRODUCTION.

The electrical energy necessary for the operation of the talking circuits and the various relays, magnets and signalling devices at very small manual exchanges is usually obtained from primary batteries. These batteries are not capable of meeting the requirements of the larger exchanges and installations where automatic switching plant is employed and it is necessary to use secondary cell batteries for these cases. As the majority of new exchanges are of the automatic type, nearly all new power plant installations employ secondary cells, and this paper is devoted to the considerations relating to this type of plant.

Until about 1936 all secondary cell installations were operated on what is known as the " charge-discharge " system. Two batteries, each capable of supplying the exchange load for at least 24 hours, were installed. The batteries were connected to the exchange in turn and re-charged when necessary.

During the 1934-35 session a paper, " Modern Tendencies in the Supply of Power to Telephone Exchanges," was read to various centres of this Institution by Mr. H. C. Jones.[1] The paper described three types of power plant which were being introduced to supersede the "charge-discharge" system; the basic principle of all three being that the output of the charging plant is applied to the battery whilst the latter is connected to the exchange.

The smallest of the three types was designed to cover exchanges requiring up to 100 A/hrs. a day. Rectifiers are used for charging and consequently the plant is only suitable for use in areas where an A.C. public supply is available. One main battery is provided and is kept in a fully charged condition under automatic control. For these reasons the plant is known as the single battery automatic power plant. A large number of plants of this type are now in use throughout the country, mainly at U.A.X's 12 and 13.

The second type of plant is designed for larger exchanges where the ultimate daily load will be between 100 and 2000 A/hrs. per day. This plant is of the automatic type also. Rectifiers or motor generators are used for suitably converting the public electricity supply for charging the battery which consists of two batteries of equal size connected in parallel, hence the title " Parallel Battery Automatic Power Plant." This type of plant will probably be best known as the U.A.X.14 Power Plant which has identical principles of design.

In the two schemes which have been outlined the batteries are permitted to discharge by about 4% of their capacity before the charging current is applied. Compensation for the rise in battery voltage, resulting from the application of the charging current, is obtained by introducing counter E.M.F. cells into the discharge circuit under automatic control. These cells are, of course, switched out of circuit when the voltage falls after the charging plant has been disconnected.

The third and largest type of plant is known as the Divided Battery Float Power Plant from the fact that the two batteries alternate for weekly " in use " and " rest " periods in contra-distinction to the parallel battery scheme. Motor generators operating with automatic voltage control equipment provide practically the whole of the power required to operate the exchange. The rest of the power is obtained from the floating battery and is replaced by re-charging the battery during the week it is not in use. It is of interest to note that two installations with a designed capacity of 100,000 A/hrs. a day and capable of meeting a peak load of 10,000 amps. are now in operation. The very large battery capacity which would be necessary for such cases makes the use of a single " charge-discharge " plant impracticable.

DEVELOPMENT CONSIDERATIONS.

Experience gained from the operation of these present standard schemes during the last few years confirms that the principles of design are sound and that there is little if any advantage to be gained by altering the basic principles of design or scope of application. Due consideration was given to the possible use of constant voltage rectifiers for power conversion at automatically controlled installations, but the increase in battery voltage due to the periodic charge necessary to condition the battery would still require correction by means of counter E.M.F. cells. This, coupled with the fact that the constant voltage rectifiers would need to have a larger capacity than the present type, is the reason for the decision to adhere to the counter E.M.F. cell switching systems.

It is well known that a designer takes care that the quality of his design is not overshadowed by the indifferent performance of the equipment. Consequently a considerable reduction in equipment cost can often be effected by reviewing the design after extended operating experience has been gained with the original version. A study of the performance of the three systems had indicated where improvements were desirable and early in 1939 a start was made to re-design the parallel battery automatic power plant. This particular scheme was selected to receive first attention as being that likely to show the largest savings per installation. Good progress had been made on a design using the new 3000 type latching relay and mercury contactors. Some of the outstanding advantages of the design are:—

(*a*) with the exception of the mercury contactors all apparatus is of the Department's standard type;

(*b*) simplified circuit design using fewer relays;

(*c*) supersession of proprietary types of delay mechanism which are used to prevent incorrect switching of the counter E.M.F. cells, by the exchange time pulse system;

(*d*) about 50% saving in the cost of the control panel and in floor space requirements.

[1] I.P O.E.E. Paper No. 156.

A model was constructed and was being subjected to tests in the Circuit Laboratory when the war commenced. A report that war-time activities in a military area had resulted in the local exchange load exceeding the capacity of the power plant and that there was no space available for the accommodation of larger batteries was received at about that time. It was decided to utilise the model panel and meet this case by conversion to a modified form of parallel battery working. The plant has been completely trouble-free since installation. The test results were very encouraging, but on further investigation the difficulty of manufacturing the largest size of contactor (350 amps. rating) required for this type of plant became apparent. Information which became available at about that time indicated that whilst mercury contacts are ideal for some duties they are not satisfactory under all conditions of service, and efforts were directed towards finding a means of adapting a type of switchgear used for motor starters. Here again the stumbling block was the very small permissible p.d. across the switch contacts when carrying the 350 amp. peak current of the largest size of this type of plant, but a satisfactory design was eventually reached by using a switch operated by a motor through a reduction gearing. The scheme will be described in detail later.

EFFECT OF WAR-TIME CONDITIONS.

The provision of standby plant to cover the possible failure of the public supply assumes much greater importance in war-time than under peace conditions, and the Department's fleet of portable generating plant has received large reinforcements to cover the greater possibility of a widespread failure of the public supplies.

The suspension of the exchange conversion programme soon after the commencement of the war was bound to bring many problems regarding the power plant at the exchanges scheduled for early conversion to automatic working. In such cases the exchange equipment will probably have been extended to the utmost capacity of the building and the power plant will be working at its maximum output. The erection of new aerodromes and military training centres gave added complication to these problems because of the heavy telephone traffic usually associated with such establishments. The majority of exchanges so affected are of the CB Manual type, the reason being that automatic exchanges are likely to have been installed more recently and are therefore likely to have a larger percentage of power plant capacity in reserve to meet development. Much could be said of the power plant problems arising from war conditions. It will be appreciated that each case must receive individual consideration and that due to the urgency the action taken will, in some cases, only afford a temporary relief.

PLANT TO MEET WAR CONDITIONS.

It was stated at the commencement of this paper that the majority of exchange power plants installed before 1936 were operated on the charge-discharge system and, as was to be expected, all the overloaded plants have, up to now, been of this type. It is essential that each of the batteries used on this system shall have sufficient capacity to supply the daily requirements of the exchange so as to avoid having to charge more frequently than once a day. Any extension of capacity of such a plant must therefore include for the provision of larger batteries which may in turn demand increased accommodation. Conversion from "charge-discharge" to a float or automatic system of operation would solve the battery reserve problem in most cases as both batteries would then be kept in a practically fully charged condition. The standard automatic power plants were designed for use at automatic exchanges and are not therefore suitable for use at 24 or 40 volt installations.

The need for a special design of power plant for use where the existing plant is of insufficient capacity was soon realised, the main design requirements being:—

(1) Building alterations to be avoided (this rules out extension of the battery capacity in most cases).
(2) Fullest possible use of existing plant.
(3) Simplicity of installation and operation.

AUTOMATIC CONTROL OF GENERATOR VOLTAGE.

At about that time a system of automatic voltage control for generators operating with a floating battery was being developed.

The generator voltage control equipment used in telephone exchanges in the past has been either of the dynamometer or carbon pile types. Whilst little or no trouble has been experienced with the dynamometer instrument, the latter type has occasionally required skilled maintenance attention involving heavy travelling expenses for the manufacturer's maintenance engineer. This, coupled with the difficulty of obtaining the Swiss-made dynamometer instrument, prompted the decision to investigate the possibility of evolving a design using simple and robust apparatus which could be maintained by the exchange apparatus maintenance staff. It appeared that we had been paying for unnecessary refinement in the voltage regulators in the past and that economy could be effected by making more use of the buffer effect of the battery. Tests were made and these confirmed the impression that it should be possible to evolve a scheme using a contact voltmeter to control the switchgear for regulating the generator output which could be allowed to lag behind the load, *i.e.*, when the load is increasing, the average generator output being less than the load, the difference is taken from the battery and replaced by the excess of generator output over the load when the load is falling. A field trial of the newly designed equipment was instituted at Harrogate exchange, where the traffic had increased to such an extent that it became necessary to extend the capacity of the power plant. Accommodation at Harrogate is very limited, and by using the new float scheme the necessity of providing a new battery room, which would have been essential had "charge-discharge" working been retained, was avoided. The apparatus has functioned very satisfactorily and arrangements are in hand for similar equipment to be installed at about twenty exchanges where the power plants are proving inadequate under war conditions.

The main item of apparatus used is an adaptation of a drum switch ; a type which is used extensively on electric traction control gear. The armatures of the operating solenoids are connected to pawls arranged to rotate the shaft in the required direction. A spiral segment on the shaft makes contact between the appropriate contact fingers and the shaft is rotated through about 150° to vary the output of the generator under control between no load and full load. Two rows of contact fingers are fitted, one of which is used for each automatically controlled generator. The direction of rotation to obtain a given adjustment on one generator is reversed to that necessary to effect a similar adjustment on the other machine and consequently it is necessary to reverse the control connexions to the solenoid magnets when changing from one machine to the other. Suitably arranged segments and contact fingers fitted at one end of the shaft are used to effect this switching operation and also to disconnect the control circuit when the shaft is turned to the " OFF " position by means of the handle fitted to the shaft extension outside the cover.

A diagram of the voltage control equipment is shown in the upper portion of Fig. **1**, the lower portion of which shows the modified connections of the "charge-discharge" power board. This arrangement permits the use of either Generator 1 or 2, or both, on floating duty, but to avoid having to increase the switchgear on the existing power board, only Generator No. 2 can be used for replenishing charges. A contact voltmeter controls the stepping of the driving solenoids, SMA and SMB. The contact fingers of the rotary switch are connected to studs of

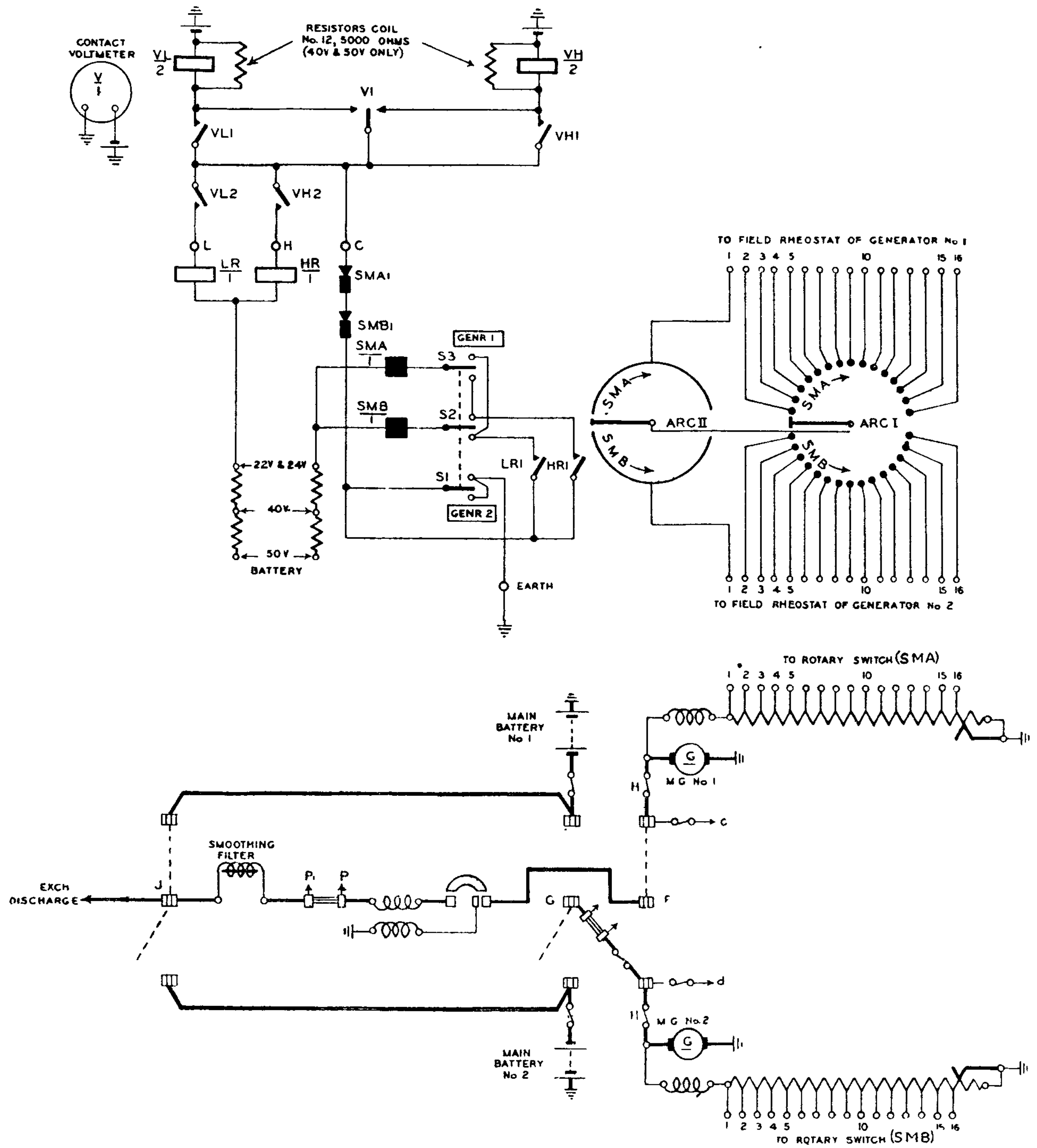


Fig. 1.—Generator Voltage Control Equipment.

the generator field rheostat which are so selected that with the manual field rheostat in a given position the rotation of the control switch through an arc of about 150° will vary the generator output between zero and full load in about 16 equal steps. The motor-generators provided at telephone exchanges can be used to supply a 25% overload for about one hour, but this extra capacity is seldom required. It can be made available when desired by increasing the output setting of the hand control when the automatically controlled range of output would be raised accordingly. It is considered that this arrangement is preferable to one giving automatic control between zero and 125% output with correspondingly coarser adjustment steps for a given switch design.

Let us assume that the apparatus is being used with Generator No. 1 at a time when the exchange load is increasing; the voltage will commence to fall when the load current exceeds the generator output and the difference is obtained by discharging the battery. When the voltmeter contact is made at the lower setting, relay VL will operate and lock *via* switch S1 (Generator 1 position) to earth. Relay LR operates from battery, LR relay coil, VL2 to earth. SMA operates from battery, switch S3 (Generator 1 position) *via* LR1 to the common earth. SMA rotates the shaft one step to short-circuit one section of the field rheostat thereby increasing the generator output. VL and LR relays release when SMA contacts open after the solenoid armature has moved through about 90% of its stroke. These contacts are held open for about two seconds after the armature has restored by means of a delay mechanism of the escapement type. This delay is necessary to allow the relays to release and for the battery voltage to respond to the changed conditions so that the control voltmeter needle will have assumed an intermediate position before the circuit is restored at these contacts and thereby preventing overdrive of the control switch.

It will be realised that such a system must result in the floating battery being cycled to a small extent and that the battery will become slightly discharged during periods of increasing load and recharged to some extent when the load is falling. This point is illustrated in Fig. 2, readings for which were taken at

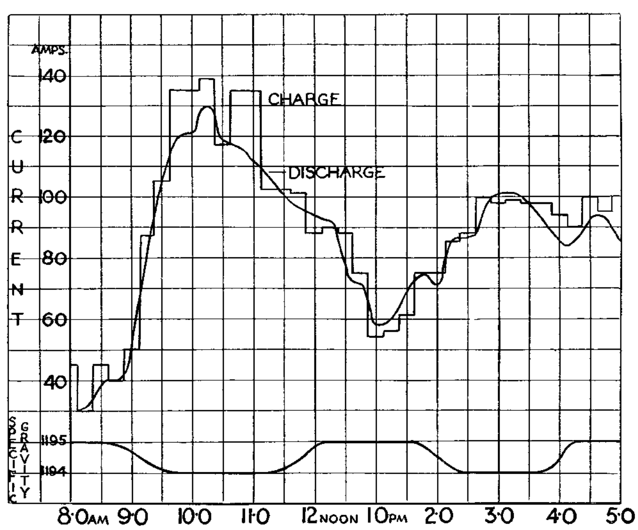


FIG. 2.—PERFORMANCE CURVE OF AUTOMATIC CONTROL EQUIPMENT.

Harrogate exchange when the field trial equipment was first brought into use, when the battery was in a partially discharged condition. The degree of cycling is, of course, dependent on the setting of the fixed contacts of the control voltmeter. Reducing the difference between the upper and lower voltage settings will increase the number of operations of the controller for a given load cycle, thereby maintaining a more constant voltage and reducing the amount of cycling of the battery. Very close settings of the control contacts would, of course, cause instability. The exchange apparatus is designed to work with comparatively wide variations in supply voltage (46 to 52 volts) so that it is only necessary to choose control voltage values which will limit the amount of cycling of the battery without increasing the frequency of operation of the controller unduly. It is found that the best performance is obtained with lower and upper settings of 50.8 and 51.9 volts respectively. With these values the floating battery is discharged about 8% of its rated capacity during a week's period of use. A similar result is obtained when using the dynamometer or carbon pile types of instrument.

It is interesting to note some of the outstanding advantages of the scheme:

(1) Its extreme flexibility in that the controller can be used with any generator used for supplying current to a telephone exchange and utilizes the normal field rheostat, whereas previous automatic voltage regulators were specially designed for use with a particular machine. The relay and magnet coils have been wound to operate on a 24-volt supply; suitable resistors are inserted in the battery supply lead when the controller is used on higher voltage systems.

(2) The apparatus is of a particularly robust and simple type so that expenditure on repairs should be negligible.

(3) Except for the few milliamperes continuous drain of the voltmeter circuit the apparatus only requires momentary current pulses of about one ampere for its operation, whereas the previous types have imposed a constant drain on the supply of one or two amperes.

(4) The initial cost is about 25% of that of the types it is intended to supersede.

It is intended to provide auxiliary contacts on the controller shaft when the scheme is developed for installation on new standard power plants. The contacts will be arranged to operate an alarm when the load has varied to such an extent as to make it necessary to increase or decrease the number of generators in use.

The existing field rheostats at telephone exchanges have no readily accessible points at which connexions can be made to the resistor terminals, but it is a fairly simple matter to fit a connexion strip to the rheostat framework and connect the terminals to the rheostat studs. The appropriate resistor values can then be selected without difficulty when the apparatus is brought into use. Field rheostats of the graded resistance type are not suitable for use with this scheme as it is possible that the portion of the rheostat which would only have to carry the minimum field current when the generator is being used with hand control will have to carry the maximum field current when the set is operating under automatic control.

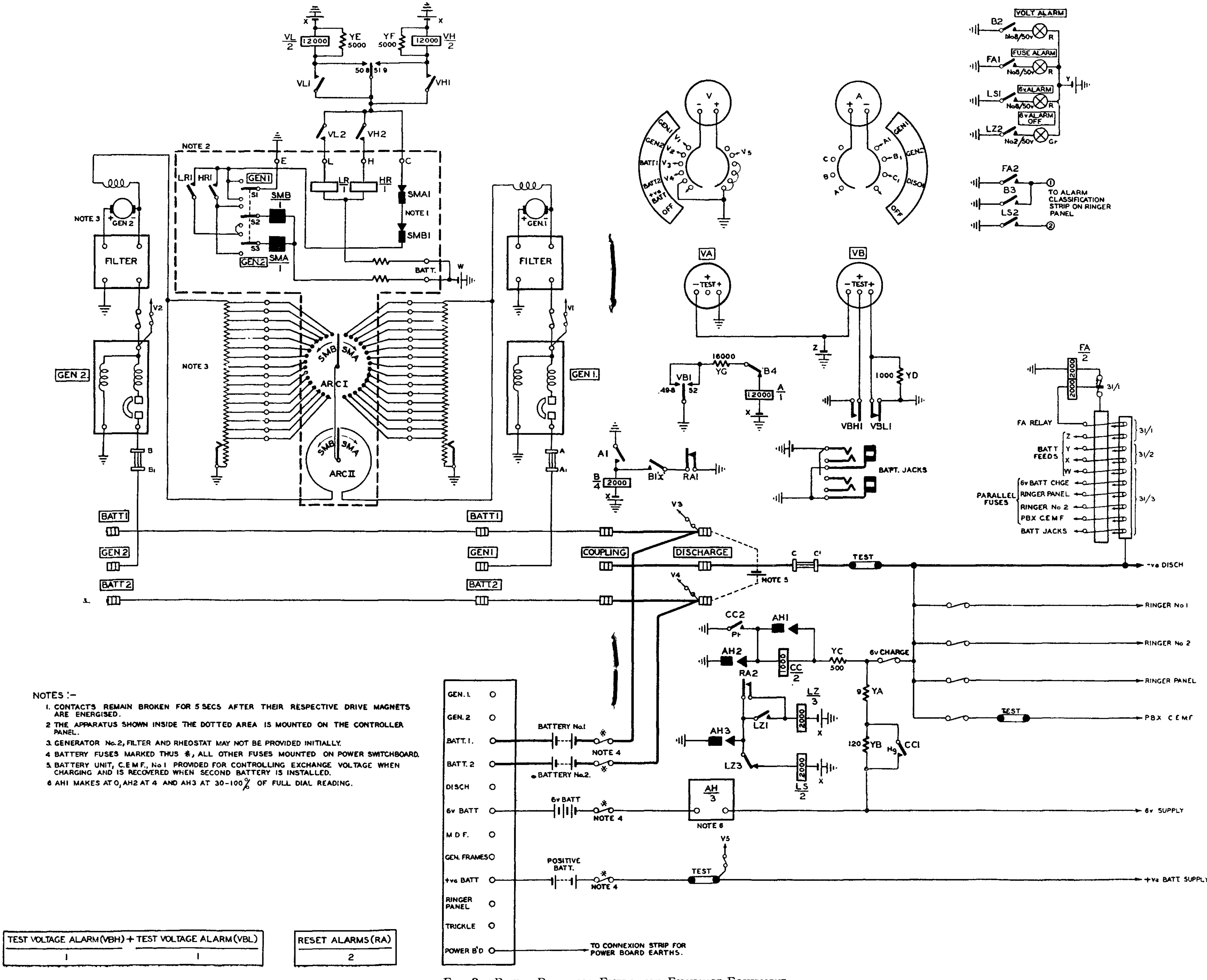


Fig. 3.—Power Plant for Emergency Exchange Equipment

POWER PLANTS FOR SEMI-AUTOMATIC EXCHANGES.

The first semi-automatic exchange installed to replace one destroyed by enemy action was equipped with a power switchboard of a type developed for fire emergency use. Such boards are designed for use with a single main battery. The battery supplies the exchange requirements during periods of light load and is recharged and floated during the day. Voltage regulating C.E.M.F. cells of the alkaline type are introduced manually into the discharge circuit, as required, to compensate for the increase in battery voltage resulting from the application of the charging current. Such a system demands frequent attention at the power board to counteract the effect of variations in the exchange load.

The Harrogate trial had proved satisfactory and the scheme was receiving further consideration when instructions to increase the reserve of semi-auto emergency exchange equipment were received. It was decided that sufficient power plant to provide nine separate installations should be obtained and that the plant should be of a new design; the main requirements being:—

(1) Standard system of operation. (*i.e.*, either charge-discharge, divided battery float or parallel battery automatic system.)

(2) Capable of being operated with a minimum of plant initially and of being extended to provide the ultimate power requirements of an average exchange having 4000 subscribers.

(3) Ease of installation.

The "charge-discharge" system was rejected in favour of a floating scheme so that the plant could be operated with only one battery. It is considered that the maximum day load of a semi-automatic exchange will not exceed 2000 A/hrs. Such a load would normally be met by the provision of a standard parallel battery automatic system, but the greater flexibility of the divided battery scheme was responsible for the decision to base the design on this system.

A diagram of the power plant developed for this duty is shown in Fig. **3**. The initial provision for such a power plant will include the following items:— One 25-cell 500 A/hr. battery of the traction type, a battery and generator control panel, one motor generator having an output of 100 amperes at 51 volts and its output smoothing filter, a standard ringer panel equipped with two 15-watt ringing machines and automatic changeover gear for changing over from the normal to standby machine, and a counter E.M.F. battery unit. The batteries will arrive on site in a fully charged condition and a 50 volt supply can be given immediately the battery and power board have been erected and connected. Fig. **4** shows a front view of the control panel, which is equipped with apparatus for the control of two batteries and two 100 amp. generators. Automatic voltage control can be applied to either generator by means of the drum switch previously described, which can be seen in some detail in the photograph. The motors of the motor generator sets are constructed for use on a 400 volt three-phase A.C. supply. An auto-transformer, mounted on the motor control panel, can be adjusted to provide the necessary compensation to permit the motor to be used on any voltage between 440 and 365 volts. This covers the maximum and minimum values likely to be encountered.

Two single-phase A.C. motors, with auto-transformers to permit their use on any voltage between 200 and 250 volts, and two 220 and one 440 volt D.C. motors, together with the necessary control panels have also been obtained. These motors are readily interchangeable with the three-phase machines, so that it will be an easy matter to change the motor if a three-phase supply cannot be obtained. All machines are of the drip-proof type.

The 500 A/hr. battery will be connected to the No. 1 battery terminals on the power-board and the counter E.M.F. battery unit will be connected across the two main battery negative terminals, so that the unit can be inserted in the discharge circuit by moving the battery change-over switch to the "Battery 2" position. The generator will be connected *via* its output filter to the No. 1 generator terminals.

The small discharge currents required during the testing-out period will be obtained by discharging the battery, and re-charging when necessary; the counter E.M.F. cells being switched into circuit as required,

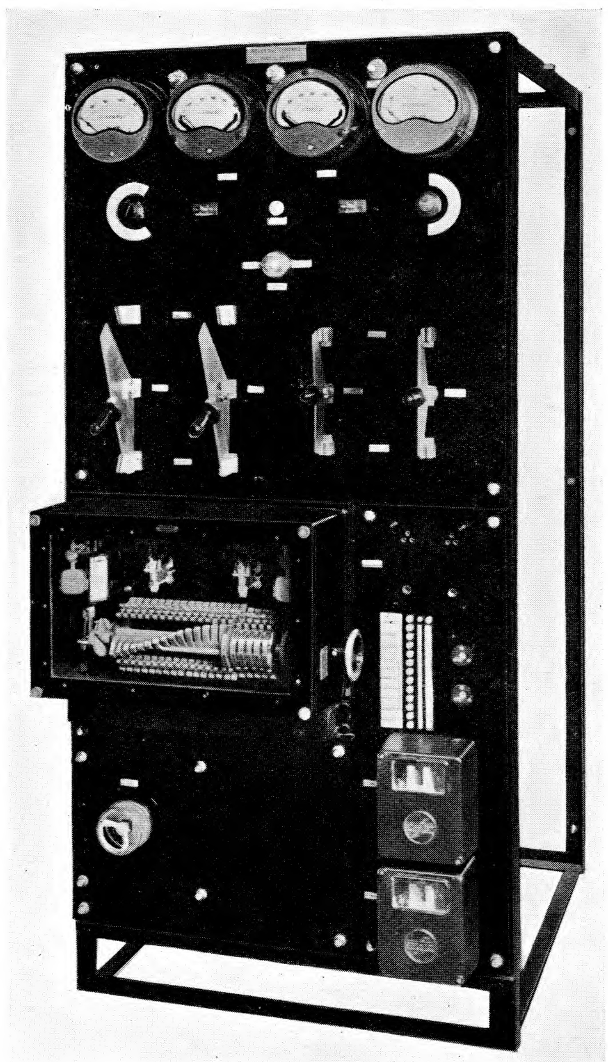


FIG. **4**.—CONTROL PANEL FOR EMERGENCY EXCHANGE EQUIPMENT.

and adjusted to prevent the voltage of the supply to the exchange exceeding 52 volts.

When the load justifies the change, the plant will be operated on a float basis under automatic voltage control during the day and the battery will be allowed to partially discharge during the night. The battery will be re-charged when convenient, using the counter E.M.F. battery unit for voltage stabilization.

Arrangements will be made for the early provision of the permanent battery plant. This will consist of two standard lead-lined wood box batteries of between 500 and 1000 A/hrs. capacity. A second motor-generator, which may possibly be a second-hand set, will also be provided and connected for use as generator No. 2. The temporary battery and the counter E.M.F. battery unit will then be recovered, and the power-plant operated on divided battery float principles. Each battery will be used with one generator with automatic voltage control to serve the exchange for a period of one week. The second machine will be brought into use when the load exceeds the capacity of the automatically controlled set. At the end of the weekly period one of the machines will be used to give the battery withdrawn from service an equalising charge at about the 15-hour rate, after which the battery will be left idle until the next change-over is due. This method of restoring the losses incurred during a floating period will supersede the trickle charge method at all divided battery float installations in due course, as experience gained during the last few years shows that very low charging rates tend to overform the positive plates. One test revealed the fact that the capacity of a battery had increased from its rated capacity of 3,000 to 3,600 A/hrs. during four years' use. This is, of course, objectionable in that the plate structures are thereby weakened.

RE-DESIGN OF PARALLEL BATTERY AUTOMATIC SYSTEM.

It will be appreciated that systems which employ floating generators of the type described in the preceding paragraph require attention two or three times during a day to adjust the number of machines in use to suit the load. This feature makes this type of plant unsuitable for use at unattended exchanges where the case for full automatic control is overwhelming.

With the Parallel Battery Automatic System, which meets the requirements of unattended exchanges, the apparatus is arranged to connect the charging current when the battery has discharged about 4% of its capacity, and to disconnect the current when the battery has been restored to a fully-charged condition. This control is obtained by means of an ampere-hour meter with differential gearing arranged so that the meter requires about 20% more energy to drive the mechanism in the charge than in the discharge direction. This feature compensates for conversion and battery losses. The cells forming the counter E.M.F. battery used to correct the voltage of the supply to the exchange are of the nickel-iron type, designed to have ample current-carrying capacity, but with little or no storage capacity, consequently the cells may be short-circuited without being damaged; this is a very valuable feature, as it enables the counter E.M.F. cell switching operation to be carried out with a simple system of make contacts, as against the elaborate make-before-break actions which would be necessary if the cells were of the lead-acid type. The present design of this type of plant employs latching contactors for switching the C.E.M.F. cells. These require fairly complicated timing apparatus to prevent false contactor operations.

The control panel which has been designed to supersede this contactor system is shown in Fig. **5**, and uses a selector switch. The contacts of the switch are arranged on parallel centre lines, and the required connexion is set up by moving a brush assembly to the appropriate position. The brush assembly is mounted on a block internally threaded, which is moved to the required position by the rotation of the square-threaded shaft on which it is carried. The drive is taken from a reversible motor *via* a reduction gear and the design is such that the switch makes a complete step for one revolution of the threaded shaft. Limit switches are provided at the end positions to prevent overdrive of the mechanism.

When the ampere-hour meter indicates 4% of its full dial reading AH2 makes and operates relay CS which connects the charging plant. Contact AH1 is made when the meter returns to zero—thus short-circuiting relay CS and disconnecting the charging plant. AH3 is provided to give an alarm should the battery become discharged to 30% of its capacity.

Contact voltmeter VA is set to the exchange voltage limits. As the voltage of the battery falls, due to the load, VA1 makes on its low-voltage contact, operating relays L and LR. LR1 energizes the appropriate field winding of the motor-driven switch, causing MS1 to step towards position 4 and short-circuit a group of C.E.M.F. cells. MS4 is operated from a cam attached to the driving shaft of the switch and provides a holding circuit for LR until MS1 has completed one step. MS4 then restores and prepares the circuit for further operation of the voltage-regulating equipment.

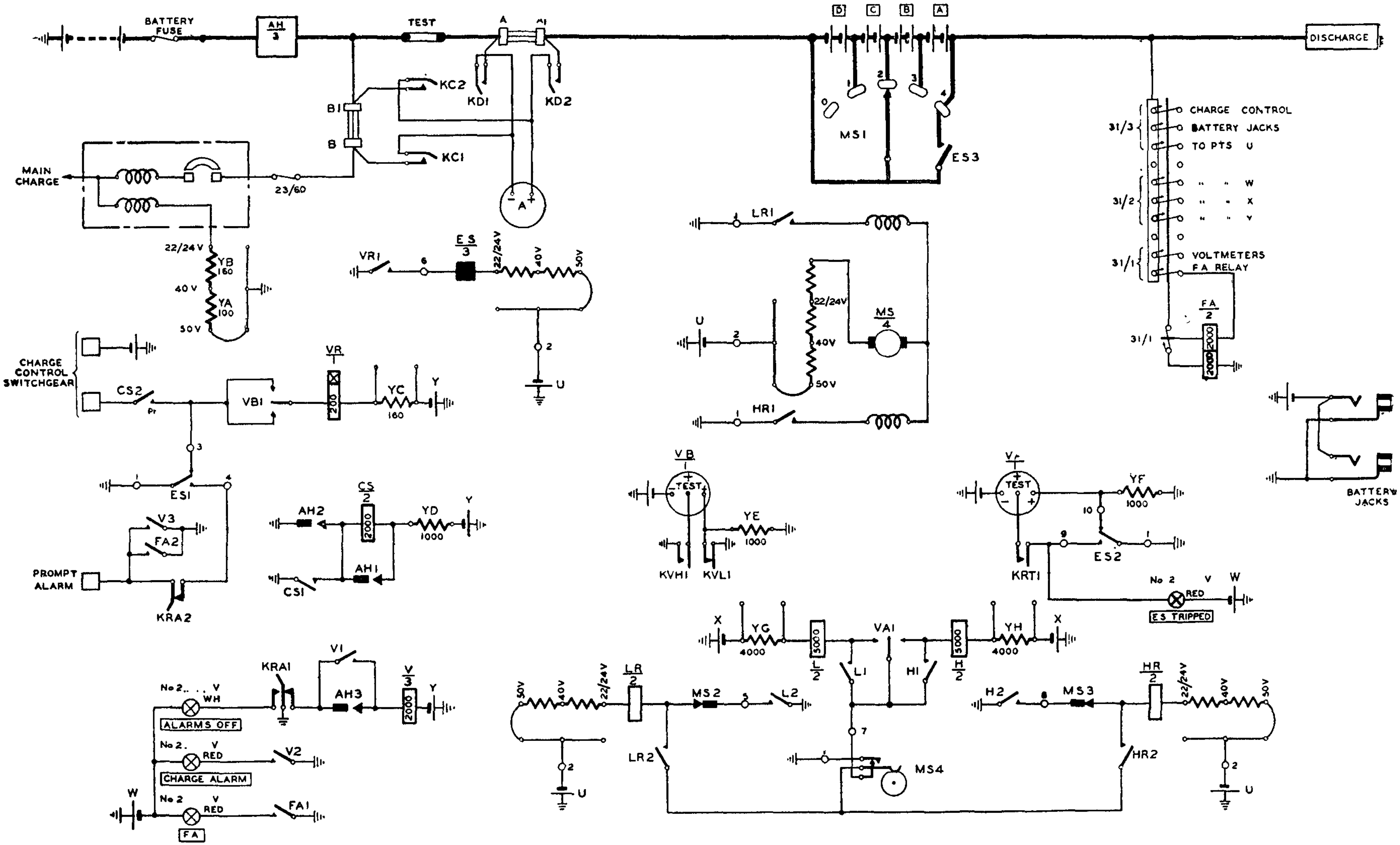
When the battery voltage rises due to the charging current, MS steps in the reverse direction to re-introduce a group of C.E.M.F. cells in circuit, to maintain the exchange voltage within the prescribed limits.

Contact voltmeter VB is set at slightly wider limits than VA and is provided to furnish an alarm if the voltage regulating equipment does not function correctly. Thermal relay VR provides a time delay, so that transient voltage fluctuations do not set up alarm conditions. The operation of VR shuts down the charging plant (if this is in operation at the time) and trips contactor ES, thereby connecting the battery direct to the exchange bus bars *via* ES3, and operating the exchange alarm at ES1.

Routine testing keys are provided to enable the maintenance engineer to apply tests to this emergency trip device. The voltage control apparatus can also be routine tested after the counter E.M.F. battery has been short-circuited by the operation of the emergency trip switch.

Some of the advantages of the new design over the panel it is designed to supersede are:—

(1) The circuit arrangements are much less complicated.
(2) All apparatus, with the exception of the motor-driven switch, is of the Department's standard type.
(3) Less floor space occupied.
(4) Reduced cost.



TEST VOLT ALARM LOW (KVL) + HIGH (KVH)	RESET ALARMS (KRA)	CHARGE (KC) + DISCHARGE (KD)	ROUTINE TEST (KRT)
1 + 1	2	2 + 2	1

FIG. 5.—PARALLEL BATTERY AUTOMATIC SYSTEM CONTROL PANEL.

The present system requires a contactor for each voltage adjusting step of the control gear, and in order to economise in switchgear, a group of two counter E.M.F. cells are switched at each operation. As the voltage of each cell is approximately two volts, the exchange supply voltage is periodically increased or decreased in four-volt steps, and in order to guard against the possibility of hunting by the control apparatus, it is necessary to set the control contacts at 47 and 52 for the lower and upper voltage limits respectively. This results in the exchange supply voltage being less than the nominal value of 50 volts for very long periods.

The number of contacts has very little influence on the cost of the type of switch employed in the new design, and it is proposed to adopt single cell switching so as to maintain the voltage of the supply to the exchange within closer limits.

The charging plant, which consists of dry plate or mercury arc rectifiers in A.C. areas, and motor-generators in D.C. areas, is also under review. The present practice for A.C. areas is to make an initial provision of two rectifiers, and to add a third unit when the increased load makes such an extension necessary. The failure of a rectifier unit would not, therefore, result in complete failure of the charging plant. Modern rectifier plant has proved sufficiently reliable to justify greater reliance being placed on a single unit, which could be of sufficient capacity to meet the ultimate load requirements and be equipped with some form of current-limiting device for use during the early life of the exchange, when the application of the full output to the battery might lead to difficulty with the voltage-regulating equipment. Similarly, it is proposed to discontinue the provision of a reserve motor-generator set at exchanges in D.C. areas. Such economies in design were undesirable when the present basis of design was formulated, as they would have introduced a risk of failure of the exchange power supply in the event of failure of the charging plant, but the number of portable charging plants which can now be made available at short notice has reduced this risk to negligible proportions.

RE-DESIGN OF SINGLE BATTERY AUTOMATIC SYSTEM.

Developments in connexion with the automatic power plant used at the smaller U.A.X's are also in progress. The object of these is to eliminate the apparatus which has proved most prone to failure and to evolve a design making the fullest possible use of standard apparatus. The exchange supply voltage is being given close consideration with a view to reducing the wide range of voltage obtaining at these installations. The fact that the voltage of the nickel-iron type of counter E.M.F. cell is to some extent dependent on the current passing through the cell makes it unsuitable for use at the smaller exchanges where the discharge current can fall to zero for many hours during periods of light load, and for this reason lead-acid cells are used to form the counter E.M.F. battery. This in turn prevents the use of a simple short-circuiting switch for control purposes and demands the provision of a make-before-break change-over action. Two tilting type mercury switches are used to perform this operation. Each switch controls a group of two cells and as the cells are always in a fully charged condition each switching operation results in considerable change in the voltage of the exchange supply. It would be an easy matter to devise a contactor scheme to switch individual cells and capable of dealing with the small discharge currents (about 15 amps. peak), but the cost of such a system would be likely to prove prohibitive. It is, of course, very desirable to use a single magnet system to control all switching operations, but the momentary current (about 40 amps.) which flows from the counter E.M.F. cells during the switching operation would prove disastrous to metal contacts unless very fast operating switchgear was used, which again would mean increased cost.

A switch and dry plate rectifier unit has been designed to overcome those difficulties and is shown in Fig. **6**. The switch arm, which is moved to the required position by the operation of the appropriate

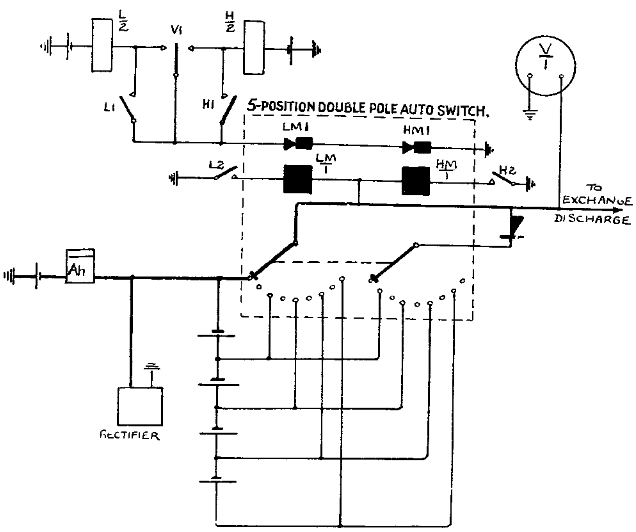


FIG. **6**.—C.E.M.F. CELL SWITCHING CIRCUIT FOR SINGLE BATTERY AUTOMATIC SYSTEM.

magnet, carries two brush assemblies arranged to sweep separate contact arcs. One brush is connected *via* a rectifier element and the other directly to the exchange negative supply terminal. The contact arc connexions are so arranged to maintain the supply to the exchange *via* the rectifier element, during that portion of the operating period when the circuit *via* the main brush is interrupted. The rectifier eliminates the heavy current which would flow during the contact bunching period of a make-before-break operation and, although it must be capable of carrying the exchange load momentarily, it is only required to withstand the voltage of a single cell and is therefore relatively cheap. A field trial has shown that the adoption of this scheme will enable a panel providing for much closer control of the exchange supply voltage to be produced at less than the cost of the present type.

PROBABLE EFFECT OF NEW POWER PLANT DESIGNS ON VOLTAGE OF SUPPLY TO EXCHANGE.

Having outlined the development tendencies of the modern types of exchange power plant it is now convenient to consider their possible effect on the telephone exchange switching plant. This equipment is designed to give satisfactory impulsing performance when operated over circuits of a specified maximum resistance provided the supply voltage is maintained between 46 and 52 volts.

The lower value, which is the minimum permissible voltage for a 25-cell battery when it is being discharged at the 9-hour rate, is not reached during every discharging period, but at the installations where the plant is being operated on the " charge-discharge " system the battery voltage frequently falls to 48 volts towards the end of the discharge. Such a condition will not arise where the plant is operated on a floating basis and, except in case of failure of the public supply, the voltage is maintained within limits which are dependent on the type of power plant and are summarised as follows:—

an extent that the voltage has fallen below the nominal value.

There is no doubt that the present standard voltage limits (46-52) used for equipment design purposes can be narrowed without undue risk and that the schemes which have been described can be relied upon to maintain the voltage at the apparatus terminals between 49 and 52 volts.

Considerable economy in plant could be effected if these closer voltage limits were adopted as standard. For example, the maximum permissible resistance of certain types of circuits used for dialling traffic could be raised by about 25 per cent.

There would probably be some little difficulty in obtaining the closer voltage control at those small U.A.X's having a D.C. or no public electricity supply.

System.	Serving Exchanges.	Voltage Limits at Power Board.	
		Present.	Proposed.
Divided battery float	of the largest type	50.5—51.75	50.8—51.9
Parallel battery automatic	U.A.X's 14 and larger exchanges up to about 4000 lines	47—52	49.8—52
Single battery automatic	U.A.X's 12 and 13	46—52	49.2—52

With the exception of the smaller U.A.X's where, due to the short lengths of relatively large cable employed for power distribution the overall voltage drop can be ignored, the exchange power distribution systems are designed so that the overall voltage drop between the battery terminals and the most distant fuse panel does not exceed one volt when the conductors are carrying the exchange peak load current. If allowance is made for the fact that such loads are, if ever, very seldom reached before extension of the exchange equipment makes it necessary to increase the capacity of the distributors, it is reasonable to assume that the voltage drop between the power board and the remote fuse panel will not exceed 0.8 volts. Applying this figure to the proposed minimum voltages at the power board gives minimum voltages at the apparatus terminals of 50 and 49 volts for the divided battery float and parallel battery automatic systems respectively when operating under normal conditions.

Except for the largest installations which are provided with an alternative source of supply, the total battery capacity is sufficient to supply the exchange load for at least 24 hours. In the event of failure of the public supply the voltage of the battery will fall to some extent, depending on the discharge current, but the large number of portable engine generating sets which have been provided to meet war-time conditions should enable sufficient standby plant to be moved to an affected area and brought into use long before the batteries have become discharged to such

The D.C. cases would probably be met by using a small dynamotor to convert the local supply to A.C. and installing a standard automatic system. The present method of " charge-discharge " working with a small engine generating set for charging would be retained at those exchanges where a public supply is not available. A simple voltage alarm could be provided to ensure that the exchange voltage is not allowed to be less than the prescribed minimum value for any length of time.

CONCLUSION.

This paper has dealt mainly with the power plant required to operate standard automatic exchanges, *i.e.*, 50-volt systems, but the schemes have in fact been developed for use in connexion with all types of telephone exchanges and could, of course, be applied to meet the requirements of other telecommunications services.

In this connexion it appears that the adoption of two or three voltage values as standard for future development on telecommunication services would effect considerable economies in capital and operating costs.

This paper would not be complete without a word of thanks to Messrs. E. N. Bray Ltd., the switchgear manufacturers, for their very willing co-operation in the design of the switchgear used and for the loan of photographs. Thanks are also due to members of Regional and Harrogate offices for their assistance during the preparation of the paper.

Dorling & Co. (Epsom) Ltd., Printers.