A Supervisory Control System for Traction Substations

Equipment Designed for The Melbourne and Metropolitan Tramways Board

By C. L. Steele*

The Melbourne and metropolitan tramways board controls and operates 19 substations, of which 15 are fully automatic unattended stations and account for 90 per cent. of the total output. The practice adopted in running these unattended stations will be best understood from a consideration of the daily load programme. The diversity factor and the regular schedule of loading is covered by starting each station by time-switch set according to the rostered load in its vicinity. In the case of two-unit stations, the second machine is brought on line when the demand on the station exceeds the safe load of one machine, and shuts down again when the load returns within the compass of one machine. By carefully-studied setting of the working limits of the second machine, known as the "trailer" in contradistinction to the "leader," a very satisfactory and flexible system has been developed. The number of operations of the trailers is a minimum, yet the leaders are never overloaded. Further, in event of failure of the leader, either at starting or while running, the trailer will at once take its place. The machines are "changed over" each week, that which was "leader" this week being made "trailer" next week, and vice versa. This evens up the wear, and is effected by means of a multiple double throw switch in the station. All feeders are kept constantly alive, and are, of course, equipped with automatic reclosing panels, with one spare or auxiliary panel in each station.

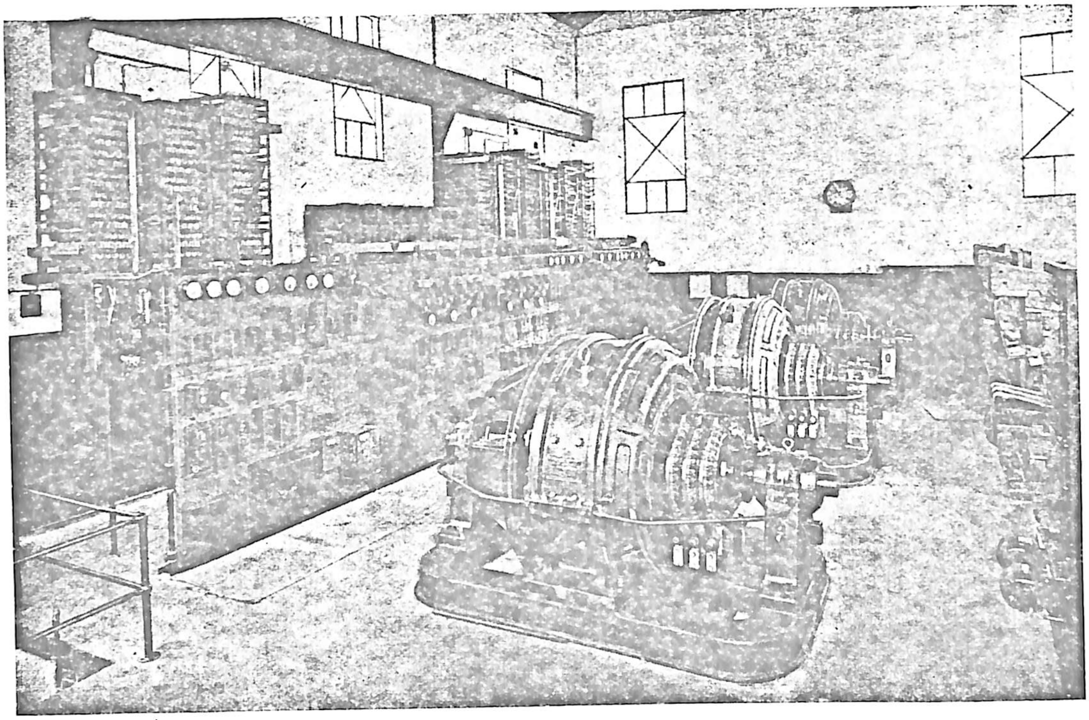

Fig. 1.—St. Kilda Substation of the Melbourne and Metropolitan Tramways Board, with three 1,000-kw. English Electric Rotary Converters and G.E. Switching Equipment

As the work of installing the automatic stations was progressing, the necessity for knowing how these unattended plants were faring forced attention to the matter of supervision. At first this took the form of simple annunciators, operated over one or two telephone "pairs" rented from the postmaster-general's department. Very early, however, it became apparent that in so complex an overhead system, fed from so many substations, some more exact and complete indication was needed. Owing to the distance involved—in most cases from four to six

*Electrical Engineer, Melbourne and Metropolitan Tramways Board miles—between the control room and the stations, it was impracticable to use separate wires for each signal, owing to the high annual rental involved. Further, there were no convenient places, such as signal boxes, adjacent to the stations, into which the pilot lines could be run to give a record of the conditions. Some means of remitting a number of signals over the fewest possible pilot lines had to be found.

There were a number of equipments available, based on telegraph, telephone, or some special form of selective signalling, and after a careful inquiry, a Westinghouse all-relay synchronous

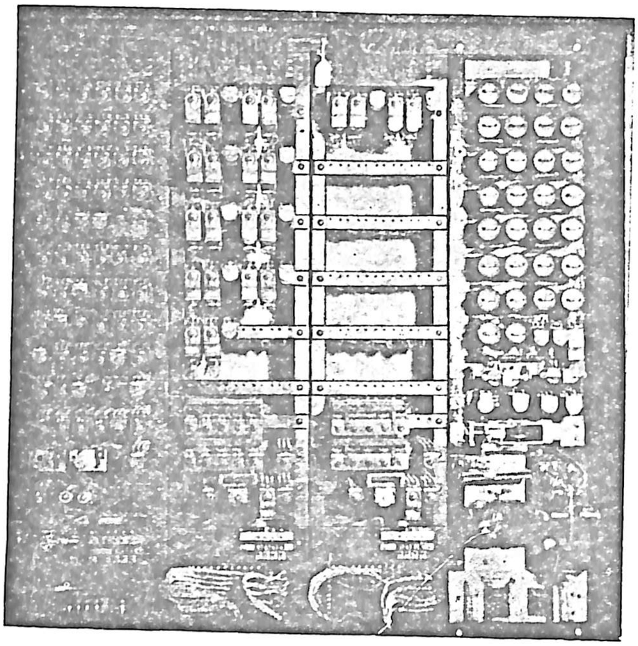

Fig. 2.—Relay Rack at Control Room End; Westinghouse All-Relay Equipment
Section at extreme right shows Richmond and Crombie Lane experimental equipment.

visual system was purchased and installed early in 1927. This equipment gave a measure of control, supervision and metering over the St. Kilda substation, some six miles away from the control. Two telephone pairs, rented from the postmaster-general's department, formed the connecting link between the substation devices, i.e., machines, feeders, and instrument transformers, and the miniature switchboard at Carlton. These four wires were able to serve the whole requirements of the three 1,000-k.w. English Electric rotary converters with G.E. automatic switching equipment, seven G.E. 600-volt., 800-amp. automatic reclosing feeder panels, two high tension a.c. wattmeters and two high tension a.c. voltmeters on the two incoming high tension feeders, and also the telephone, which was linked up with the board's private magneto system. This was effected by means of two groups of relays, located one in each station, and so connected over the lines that the two groups operated simultaneously through a given cycle, and at definite points in the cycle they connected the pilot lines momentarily in consecutive sequence from each remote device to its control room counterpart. During this brief period of connection, the substation device sent through a signal of its position or indication to the control room, where it was translated into the conventional red or green light. When, however, it was desired to operate a device from the control room, the relays were set off as before to switch the lines from point to point, until they reached the device it was intended to operate. Here they were brought to

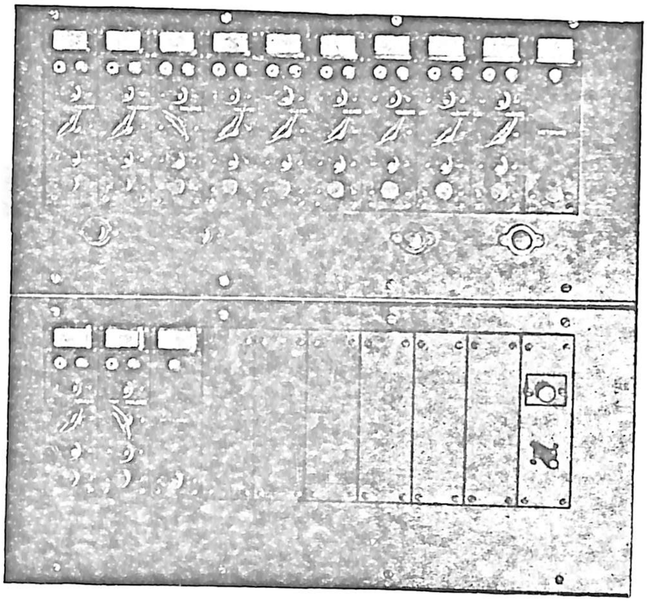

Fig. 3.—Control Desk for St. Kilda Substation

rest, because of the stop button for that device having been operated by the supervisor. There were then two solid metallic circuits extended from the miniature switchboard at Carlton to the device in question at St. Kilda. When the supervisor turned the control key to the "trip" or "close" position and pressed the master control button, an impulse was transmitted to the relays at St. Kilda, to carry out the desired operation, and over the second circuit the signal came back to Carlton in answer, to change the red and green lamps. At the conclusion of the operation, the supervisor released the stop button, and the relays carried the pilot lines on from point to point till they completed their sequence and came to rest. This system was most flexible, and, despite its somewhat complicated circuits, it has given very reliable service. This installation, however, only provided control for one station. Something had to be done about the rest.

In order to obtain an idea of the position of each circuit breaker in the outlying station, a system was devised, wherein each such circuit breaker was caused to vary the current in the pilot lines by cutting in a definite number of cells of a local battery (Fig. 4). By fitting contacts to the pointer of the milliammeter used to record the changes of current in the control room, a circuit was arranged to drop a shutter and sound a buzzer whenever the pointer moved from the "normal" position. A small current was passed over the lines continually to act as a police current, and to cause the milliammeter to give notification of any defect, such as low battery, open or short circuit in the lines, etc. This current gave the "normal" position. By suitable spacing of the pointer positions—actually only four or five indications were allotted to any one meter—a reasonably satisfactory system was evolved. Its most severe limitation was its inability to indicate the simultaneous operation of two or more circuit

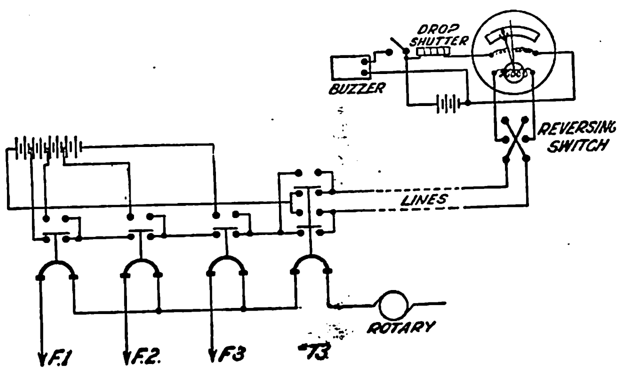

Fig. 4.—Meter System

breakers. From the figure it will be clear that if more than one circuit breaker were open, only that one which had the highest reading could be signalled. In practice over several years, however, this defect has caused singularly little trouble, and it is questionable whether the considerable extra expense involved in providing a more perfect system of indication would be warranted by results in the case of those smaller and less important stations to which this equipment is applied.

It was deemed advisable, however, to have a separate indication of the position and operation of the machine circuit breakers, as while all feeders are normally closed on, the machines of course run to a schedule. Also in case of a feeder opening, it is often important to know if the machine were opened off as well. This separate indication was achieved by causing the machine circuit breaker to reverse the current over the lines. At the control room a second "reversing switch" in the form of a telephone key was used to re-reverse the current into the meter. Thus when the machine circuit breaker operated and reversed the current over the lines, the meter would attempt to read below zero, and in so moving it made a contact which dropped the shutter and sounded the buzzer as before described. On seeing the nature of the indication, i.e., reversed reading, the supervisor reversed his telephone key, thus restoring the pointer to normal. The position of the telephone key therefore gave the indication of the position of the machine circuit breaker, because if it did not correspond, the pointer would cause the various alarms to be energised. The whole scheme was very cheap and over some six years has given surprisingly good results.

However, the fact that it was impossible to obtain any measure of control when required with this system in addition to the disabilities already mentioned, led some of the board's staff to endeavor to find some simple scheme that would overcome these troubles as cheaply as possible. The turn of world affairs during recent years also caused stress to be laid on the question of cost. Despite lack of complete information on the subject, the high cost of such schemes as were on the market forced those who were interested to attempt to develop a scheme of their own. Certain domestic arrangements made possible a very large reduction in developmental costs, and thanks to the co-operation of the officers concerned, facilities were extended for preliminary investigations.

The chief characteristics required of the scheme were as follows:—

1. Indication of position and operation of circuit breakers.
2. Possibility (though not necessity) of control of remote devices.
3. Use of as few pilot lines as possible.
4. Low first cost, and cost of erection and maintenance.
5. Reliability; equipment faults must not affect substation plant.
6. Low battery consumption.
7. Simple circuits and standard parts.
8. Tandem circuits not required, although not vetoed.

This looked a formidable list, but an idea conceived quite early in the quest proved so promising that it has been followed up, and although the search has since covered every known type of equipment, the early idea is still found to be best suited to the board's requirements. It is quite recognised, however, that it would not, and does not suit a number of other situations, but then it has been designed for one particular task, and so is a specialised type.

The idea is in essence that the pilot lines are connected to rotatable arms which move over contacts associated with the devices it is intended to supervise. If both ends of the line are connected to similar arms which are moved synchronously, then at any given moment the lines will be connecting some particular contact at one end with the numerically or angularly corresponding contact at the other. Fig. 5 shows the arrangement in schematic form. L_1 and L_2 are two wires of a pilot line the ends of which are connected to the arms A and A_1 and B and B_1. These rotary arms, which are mounted in pairs on common shafts, i.e., A and B on one shaft and A_1 and

B_1 on another, move over contacts as 1a, 1b and $1a_1$, $1b_1$, also 7a, 7b and $7a_1$, $7b_1$. Now when arms A and B are resting on contacts 1a, 1b and arms A_1, B_1 are resting on angularly corresponding contacts $1a_1$, $1b_1$ then a circuit is formed from battery 1 via switch 1, over the lines to relay 1, so that if the switch be operated the relay will respond. Similarly if both arms are moved in synchronism to contacts 7a 7b and $7a_1$, $7b_1$ a circuit will be formed from battery 2, via switch 7 over the lines to relay 7. It will be seen that as many device circuits may be formed as there are contacts for the rotary arms, and that so long as the arms are moved synchronously the corresponding switches and relays will always be correctly connected. Thus the apparatus may be regarded as a means of switching the

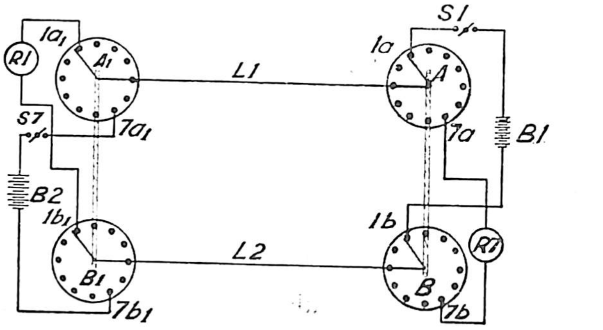

Fig. 5.—Selective Switching

pilot lines in turn from device to device in a definite sequence. This makes possible the operation of a number of devices over a single pair of wires by allowing each device the use of the wires in turn.

The matter of keeping the ends in phase and in synchronism is of course the essence of the system. In this case a very simple arrangement of polarities, found since in many similar applications, was used and found to be entirely satisfactory. At first motor-driven commutators were suggested, but as manufacturing and development costs promised to be unduly high, enquiry was made for something in the way of a standard apparatus that could be purchased, maintained and operated at lowest cost, consonant with satisfactory reliability. Very quickly the choice fell on the Rotary Switch, Stepper Switch or Uniselector as it is variously known in automatic telephone parlance (Fig. 6). This supplies as many as eight arms, if needed (although only from four to six were used), moving very definitely over suitable banks of contacts (in this case 25 contacts per bank). Its power requirements are relatively low and it is quite a precision device. Although its application demanded some modification of the original scheme, it held such advantages in reliability and standardisation, as well as flexibility, as to make it pre-eminently the appliance for the job. Subsequently it was decided to drop the idea of using specially built power type relays and apparatus for the remainder of the equipment as had been originally intended, and to use all standard telephone apparatus throughout. This at once brought the equipment into line with the requirements set out. It has been interesting to notice that within the last year or so practically every manufacturer of supervisory equipment has turned to standard telephone equipment for his product.

Circuit details were completed, and in March 1930 a trial equipment, built up with such apparatus as was to hand or could be purchased locally was put into operation between the control room and Crombie lane substation, over some two miles of p.m.g. pairs. It afforded indication and control of certain feeders in the substation, and despite the severe limitations imposed by the nature of the apparatus of which it was built, it

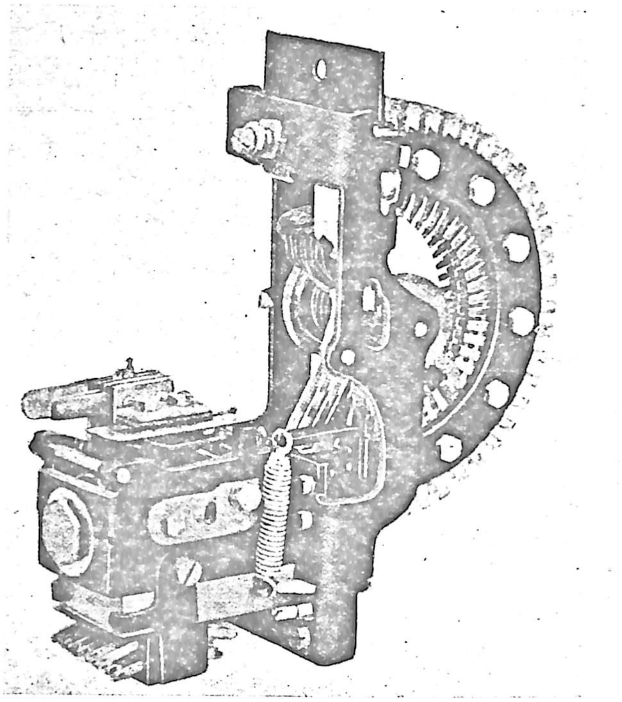

Fig. 6.—A Typical "Stepper," manufactured by Siemens Bros. and Co. Ltd., London.

gave quite a creditable performance and proved the correctness of the ideas involved. After some 12 months trial and observation it was decided to equip a larger and more important station, and eventually the two 1000-k.w. rotary converters and six 1200-amp. G.E. automatic reclosing feeder panels at Richmond were connected up, with provision for a particular form of control over the method of starting the leading unit. This equipment, although all second-hand and much of it of an unsuitable type, gave excellent service for six months, in which time it performed the rather surprising total of over 4,000 operations with only two faults, both of which were caused by the second-hand apparatus. This number of operations included the weekly testing of both substation plant and supervisory equipment, with the addition of a fair number of demonstrations. Later the original equipment at Crombie lane was connected up again in an unusual form of tandem, and this combined equipment has been in service ever since. Recently it has been decided to extend the facilities to other stations, and a complete installation has been assembled for the Malvern substation and another is nearing completion for a glass bulb rectifier and rotary convertor station at Preston.

In order to appreciate the application of the supervisory equipment at these stations it will be necessary to be acquainted with the plant installed and the operating characteristics of the station. Malvern substation contains two 1000-k.w. English Electric rotary converters with English Electric automatic switching equipment, and 11 B.T.H. 600-volt 1200-amp. automatic reclosing

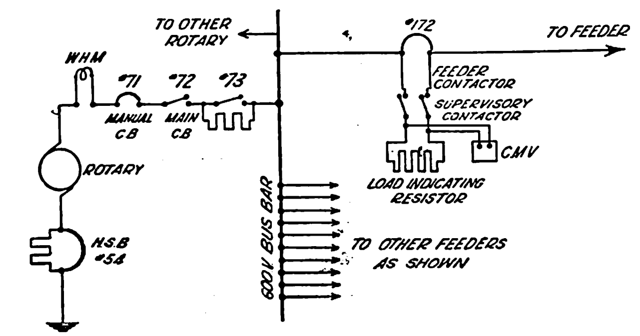

Fig. 7.—Malvern D.C. Connections

feeder panels. The first machine (leader) is started and stopped by timeswitch, and the second comes on in event of failure or of overload on the first, and times itself out when conditions have been restored to normal for a pre-determined length of time. Each machine is normally supplied from its own incoming h.t. feeder, although there is provision for tying the two h.t. buses if necessary and operating both machines from one feeder. They are cushioned on to the d.c. bus through load limiting resistors which are normally shorted out by a second contactor similar to the main contactor, and which serves also as an overload contactor. In case of a normal d.c. overload, this contactor, known as Device 73, opens, thus inserting the resistor into circuit and thereby effecting load reduction by lowering the bus voltage and so shifting some of the demand on to adjacent stations. The main d.c. connections are shown in Fig. 7 on which are given the device numbers according to the notation of the American power club. The feeders are all normally closed, except one which serves as an emergency tie feeder between two important sections. This tie is normally open, but may be released by supervisory control, when it will close, subject to its automatic reclosing features.

In deciding to fit full supervisory equipment to this station the first point to be considered was the extent to which the control feature would be warranted. The indication of the main contactors or circuit breakers, and of current and voltage of each machine were the first necessity, but the question was, how far would it be wise or necessary to superimpose on the automatic control? Experience gained with the all-relay equipment at St. Kilda, coupled with the experience of automatic substation operation in general, had led the Board's staff to the conclusion that carefully chosen automatic equipment, correctly adjusted and checked could take care of normal conditions better than any measure of manual control. Therefore it was required only that provision be made for the abnormal, which resolved itself into a question of the economic value of providing for emergency conditions that could reasonably be expected to arise. After a careful study of the possibilities, and probabilities, it was decided to instal the following measure of control:—

1. Feeders. Ability to definitely lock out a feeder including disconnection of the load indicating resistor, or to release for normal automatic operation. This facility would be used to deaden a given section of overhead in case of emergency, or where sections were fed from two or more stations it could be used as an emergency load shifting device.

2. Machines. A Three Position control was devised, and so far as is known is the first successful application of this idea in such a form. It provided means whereby the one three-position key could cause the machine to be: (a) Locked-in independent of time switch or load demand; (b) left to function automatically; (c) definitely locked out. This facility would be used if:

(a) It was desired to run the station out of schedule hours, or to run both machines and so raise the voltage slightly to assist an adjacent station when the second machine would not normally come in automatically;
(b) Return machine to normal after either locking in or locking out;
(c) Shut a machine down, or hold it out as perhaps during a brief period of abnormal light load.

The question of voltage control, or forced closing of circuit breakers was duly studied, but it was deemed inadvisable to add any such features, as the remoteness of the need would not justify the cost and added complexity.

In the matter of indication, the following was agreed upon:—

1. Feeders. Indication of operation and position of feeder circuit breaker.

2. Machines. (a) Indication of operation and position of load shifting contactor device 73. (b) Indication of position only of main contactor device 72 (obtainable on special selection). (c) Indication of which machine was leader.

3. Metering. (a) Indicating and/or graphic recording of a.c. current supplied to each machine. This reading to be available whole time supervisory equipment is at rest. (b) Indication of h.t. voltage in either h.t. feeder.

4. General. (a) A retained indication of the fact that a circuit breaker has operated. This was achieved as follows:—When a change of indication is signalled to the control room, the lamps concerned are changed from a Steady Light Bus to a Flicker Light Bus, so that whichever lamp is alight, no matter how often the indication may change, will continue the flicker until released by the turning of the position key in acknowledgement of the operation or operations. This was provided so that should a circuit breaker open, and reclose before the signal is answered, there is a continual indication of which device it was until the signal is answered.

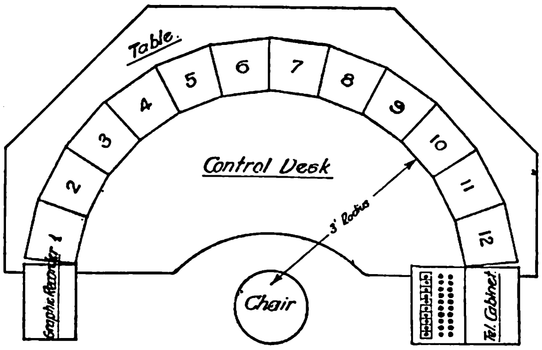

Fig. 8.—Control Desk

It was also decided to make the supervisory equipment check itself for the following faults in itself, and to give audible and visual warning:—(1) Blown fuses in either substation or control room; (2) loss of battery voltage in either substation; (3) open or short circuits in pilot lines; (4) failure of equipment to maintain synchronous stepping; (5) failure of either end to respond to start impulse; (6) ineffective control impulse. Also the telephone is continually available over the same lines, and is not put out of service by any faults in the equipment except open circuiting of both pilot lines.

Having decided on the measure of control and indication required, and the method of obtaining those requirements over pilot lines, the next question was how the facilities could best be presented to the supervisor, i.e., what form the control room switchboard should take. A study of contemporary systems showed two main lines of development. Chief of these was the use of the mimic diagram, with the indicating devices and control switches mounted in their schematic positions in the diagram. There were some very elaborate forms of this equipment, including Light Diagrams in which the mimic circuits were arranged on a colored translucent background, and were illuminated or not—or in some cases illuminated in various colors—according to the electrical condition of the circuits they represented. The other line of development, which was sometimes combined with the first mentioned was the use of a separate standard switchboard panel for each station supervised. It was at once seen that the second scheme would not do, as it was desirable that the supervisor, or rather his assistant, should be able to attend to his 15 or more substations and his telephone switchboard without leaving his chair. This was necessary to fit in with the system of working the control room. It was decided therefore, to use a miniature switchboard in which each device was represented by a panel 5 in. x 2 in. which contained red and green lamps for indication and a Position Key to answer the indication or select the nature of the control impulse and hence the position of the controlled device. In arriving at this decision considerable thought and experiment, along both physical and psychological lines, were concentrated on the whole subject of presenting the staff with the most understandable picture of the electrical conditions in the system under their care. In order to see whether the Light Diagram would be of assistance to the miniature switchboard, a carefully worked out scheme was actually built and installed in conjunction with the Crombie lane equipment previously referred to. By way of illustration of the completeness of the scheme it may be mentioned that provision was made that where a section was fed at two points from adjacent substations, the track was fully lit when both feeders were closed on, but if one opened off, that point went dim with the light graduating up to full brilliance where the feed was maintained and thus giving a picture of the voltage conditions on that section. The usual two-position operating feature, whereby the operator can see what the effect of a proposed operation will be before the executive impulse is actually sent, was also incorporated. It was decided, however, after some months of trial that the light diagram would have to be very complex indeed to give a true picture of the whole system with its wide variety of possible effects due to crossing and recrossing of tracks, parallel feeds, automatic section switches, and hand-operated aerial switches. In fact, it was evident that apart from the question of cost, it would be so complex as to defeat its own purpose.

It was decided, therefore, to rely on the indications of the substation equipment, in conjunction with the usual well set out wall diagram of the system. It will be appreciated that a street tramway system presents a very different distribution network from a h.t. a.c. feeder system. For instance the lines themselves are more than connectors between points of supply and demand, they are themselves the infinitely graded point of demand itself, since the trams draw current from their whole length and from every point in it. Even the feeders in such a system function usually simply as an external complement to the trolley wire. For this reason every portion of the network must be kept always alive, and there can be little or no voluntary re-routing of supply. Further, as power failures of even short duration result in timetable dislocation and general public inconvenience, it is necessary to keep a close check on the substation equipment. Hence the staff come to look on the substation as the centre of information about the system. The logical conclusion, therefore, is that the attention of the staff should be focussed on substation operation, with the large clearly arranged system diagram easily

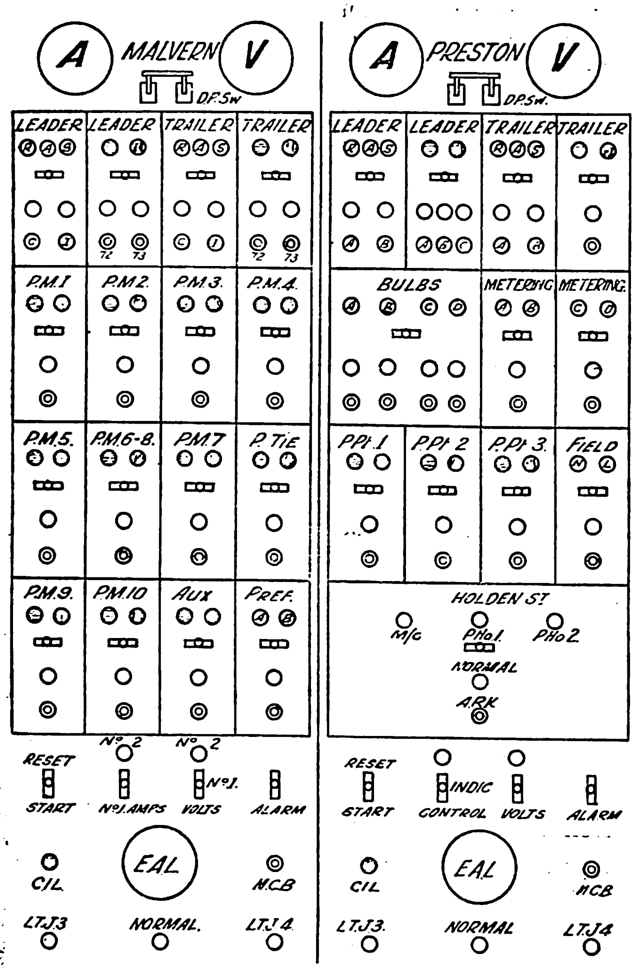

Fig. 9

visible adjacent. This presupposes that the staff, which must be highly trained, of course, will interpret substation happenings in terms of the system diagram, it being found better to allow such interpretation to be done by these trained minds, than by less flexible physical mechanisms.

Eventually the present method was evolved, in which a semi-circular 12-panel desk is used to house the complete supervisory installation for the system. Some of the smaller stations are fitted in groups of from two to six on a panel, but the more important have a panel each. The Malvern equipment being typical of the larger stations may be taken as an example. The panel is 32 in. x 9 in. (Fig. 9), and contains from the top downwards: (a) The meters for remote measurement; (b) rows of the individual plates 5 in. x 2 in., for the various devices; (c) at the base the master equipment, such as start and reset key, metering keys, alarm release key, equipment alarm lamp, (a powerful dazzle lamp which may be used in place of a buzzer to reduce noise while telephoning, etc.), master control button, supervisory lamps, and line testing jacks. Lamps which do not represent circuit breakers are not red and green but white with distinctive lettering, as for example the lamps on the three-position control panel which are white-capped and lettered R, A, and S, signifying Run, Automatic, and Stop, respectively. The machine controls and indications are kept uniformly at the top of the desk, thus avoiding possible confusion with feeders which are, as previously explained, all normally closed and are kept to the lower rows.

The next station to be equipped was Preston. The plant there comprised a 500-k.w. Hewittic glass bulb rectifier, a 200-k.w. G.E. three phase rotary converter, with automatic switching equipment designed and erected by the board's engineers, and three B.T.H. 600 volt, 1200 amp. automatic reclosing feeder panels. The rectifier carries the all-day load of the station, the rotary being used only to give assistance over the peaks, and when the rectifier is shut down for maintenance during light load periods. Both rectifier and rotary are provided with three-position control as described for Malvern, and the feeders have the same measure of control and supervision as before mentioned.

The four 125-k.w. rectifier bulbs are coupled in pairs and connected to two circuit breakers (Fig. 10). As both should close together, the Normal indication requires both to be closed to give the Closed signal. Each is connected to an individual Select button as well, so that by pressing these buttons the indication is taken away from the Normal and transferred to the individual points to show the position of each circuit breaker independently. On release of these individual buttons the indication reverts to the Normal point again. A further feature of this equipment is the means for showing whether all four bulbs are working. It was realised that should a bulb fail there would be no indication of the fact available, and the others would be unduly loaded. At first experiments were carried out using photronic cells focussed on to the cathode spots and used to operate the supervisory equipment through the medium of photronic cell relays. Time showed, however, that owing to the blackening of the rectifier glass bulbs, sufficient light energy was not available for satisfactory operation of the cells and their sensitive relays, and eventually the indication was taken from the series relay in the starting anode circuit. This gave a reliable index as to whether the bulb was functioning or not.

Experimental work being carried out on a two-wire supervisory system led to some valuable results in circuit refinements. An ingenious and effective arrangement devised by one of the staff gives the full facilities of four-wire supervision, with certain important advantages in addition, using only three wires or, where practicable, only two wires and earth return. In this equipment one wire is used as a common or neutral, one is used for maintaining synchronous switching, and the third wire is used for both signal and control impulses, the changing of the function being entirely automatic, the selection being governed by the condition of the supervised plant itself. In the case of the Preston equipment, this new circuit was adopted in order to leave the fourth wire free for continuous metering from any one of three

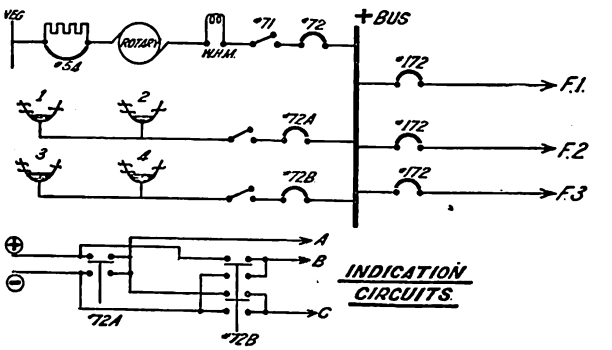

Fig. 10.—Preston D.C. Connections

scurces: (1) Rectifier h.t. amps.; (2) rotary h.t. amps.; (3) total station h.t. amps. Selection is made by a single impulse and is proved back at the same moment as the new metering appears on the instrument. The operation of the whole substation equipment, from the supervisor's point of view is practically identical with that for Malvern, except in the matter of current metering, the h.t. voltage being indicated similarly although there is only one h.t. incoming feeder at Preston.

Another feature added to this equipment was the provision of one step of field control for the rotary. A series resistor was inserted in the field circuit and normally shorted out by a contactor under the control of the supervisory equipment. The value of this resistor was such as to give sufficient voltage drop,—without undue overheating—to cause the machine to shift some of its load on to an adjacent substation. This would give a temporary relief in cases of emergency, where the rotary was called on to operate alone and the load was too heavy for its overload relays or commutator. The rotary lent itself peculiarly to this apparently rather daring manipulation and had been well tried out when under manual control before the automatic switching equipment was built. The Preston substation panel is shown in Fig. 9. The various groups are: (a) Three-position control and indication for rectifier and rotary; (b) bulb indication and metering selection; (c) feeders and field control and indication; (d) Holden street indication, to which reference will be made later; (e) master equipment (similar in general to Malvern).

Before passing on to consideration of the latest type of indication supervisory, it may have occurred to some to ask, "Why go to the expense and labor of developing these systems of your own when there are so many reliable systems on the market?" This question was answered in part earlier in this article. Actually the chief reasons were: (a) The high cost of manufactured equipments that would do all that was required; (b) the cost of installation of such a system, including the "running in" period; (c) appreciation cf the fact that equipment designed by our own staff specially for our own system could avoid certain features essential to a standardised product, but not wanted in this particular case; (d) appreciation of the fact that such equipment would be completely familiar to our own staff, thus avoiding the delay and inconvenience of having to correspond with overseas principals in case of alterations or additions, or new adaptations.

In an effort to find a cheap and reliable form of indication for the smaller stations it was finally decided to elaborate the Meter system to dispense with the meter and receive the indication on lamps. Accordingly a scheme was devised whereby the circuit breakers in the substation were arranged to vary the current in the pilot lines much as before, and a balancing relay in the control room caused a stepper switch to search its contacts for a current of similar value in a local circuit. On arriving at this contact the stepper switch would be brought to rest and caused to operate a relay, and to light a lamp which showed on which ccntact it was resting. When the line current again restored to normal the stepper switch followed suit but left the relay energised. This relay then transferred the lamp to the flicker bus, and the flickering light gave a "retained indication" of the circuit breaker operation. The alarm buzzer, which is energised whenever the stepper switch moves off from Normal, and the flickering light were released by a simple press button. The original feature of separate indication of machine position by means of a reversing key is also retained, and thus the equipment forms a compact and standard type of indicator. It has therefore been adopted for general use on small stations such as Holden Street (Fig. 9).

A new control room has just been built, into which all this new equipment will be installed. It is confidently expected that the extra facilities provided by the new arrangements will pay for themselves in a relatively short space of time, besides affording a safer and surer distribution of energy to the cars.