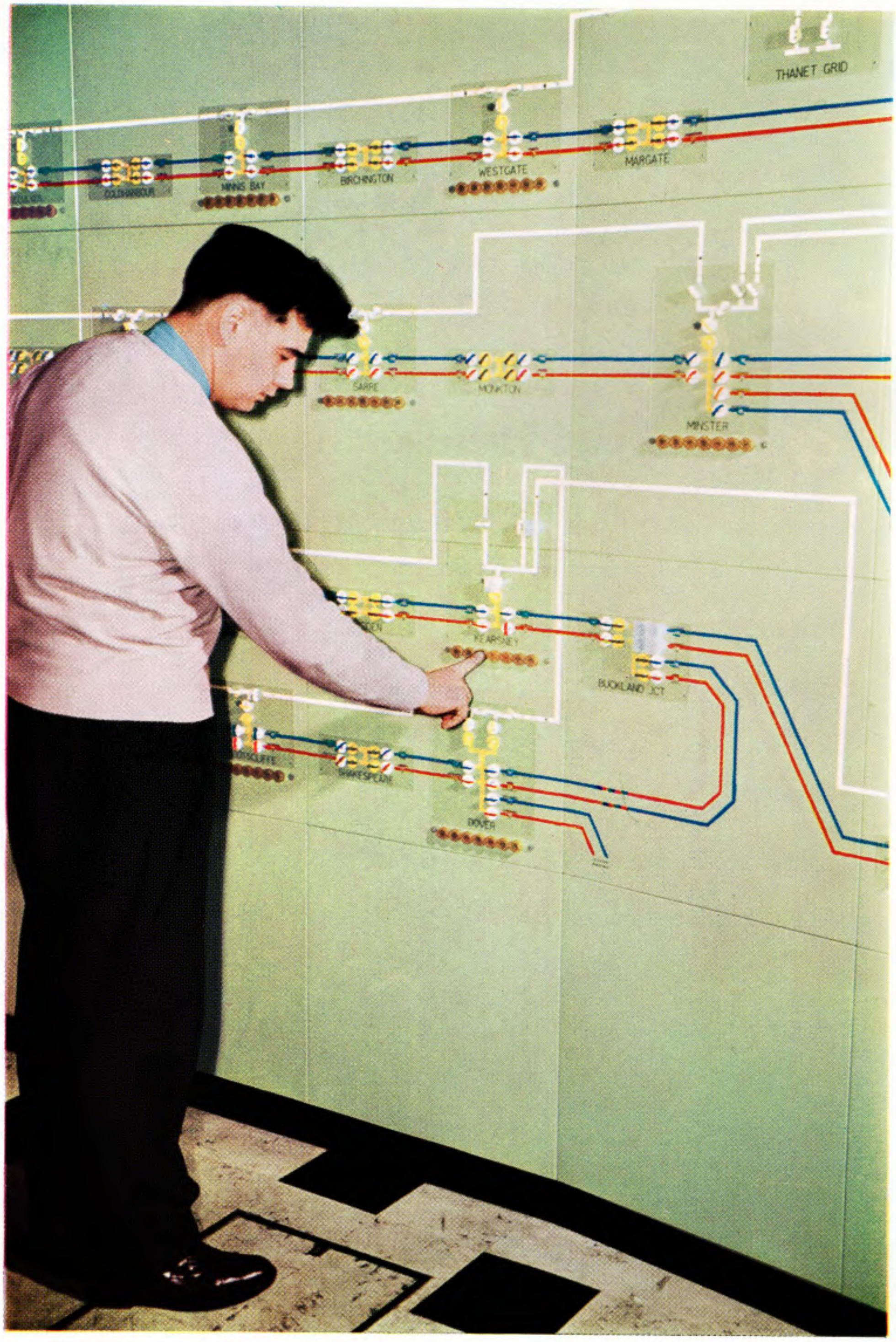

Frontispiece—Close-up of mimic diagram in Canterbury control room.

Remote Supervisory Control of Substations for the Extension of Electrification in the Southern Region of British Railways

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This article describes the remote supervisory control equipment being supplied to the Southern Region of British Railways in connection with the electrification of the Kent Coast lines. This was planned following the "Change of Frequency Scheme" for Southern Region suburban routes,[1] and is now partially completed.

The remotely-controlled mercury-arc rectifier substations are fed from a 33kV, 50c/s distribution scheme comprising a number of inter-connected ring mains fed at 33kV from six grid stations.

Interconnexion with existing 33kV railway supplies is made at a number of points where existing electrified routes are met. Power is fed to the substations over three-core oil-filled cables, and low oil-pressure alarms[2] are brought into a number of traction substations for extension to the control rooms. At the remotely controlled substations the 33kV a.c. voltage is transformed down, rectified and fed to the track at 750V d.c. Pick up is from a third rail with the return path through the running rails.

Extension of Electrification Area

The map in Fig. 1 shows the extent of the area covered by the new scheme. The first part, which consists of an area in East Kent with a control station at Canterbury controlling 24 substations, 22 track-paralleling huts and circuit breakers for the railway's high-voltage feeders in four grid stations, is now complete.

Work is progressing on the second part of the scheme, which, when complete, will comprise an area in mid and south Kent with a further 17 substations, 20 track-paralleling huts and circuit breakers for the railway's high-voltage feeders in one grid station controlled from the existing control station at Canterbury.

A second control station is being built at Paddock Wood to control 17 substations, 18 track-paralleling huts and circuit breakers for the railway's high-voltage feeders in one grid station.

Control System

Control and indication of the substation's equipment is by a four-wire d.c. signalling supervisory system. Each supervisory system controls up to four tandem systems. A further two wires for each system gives instantaneous indication of an alarm arising in any substation in that system. Track-paralleling huts and railway feeders in grid stations are satellited on adjacent traction substations.

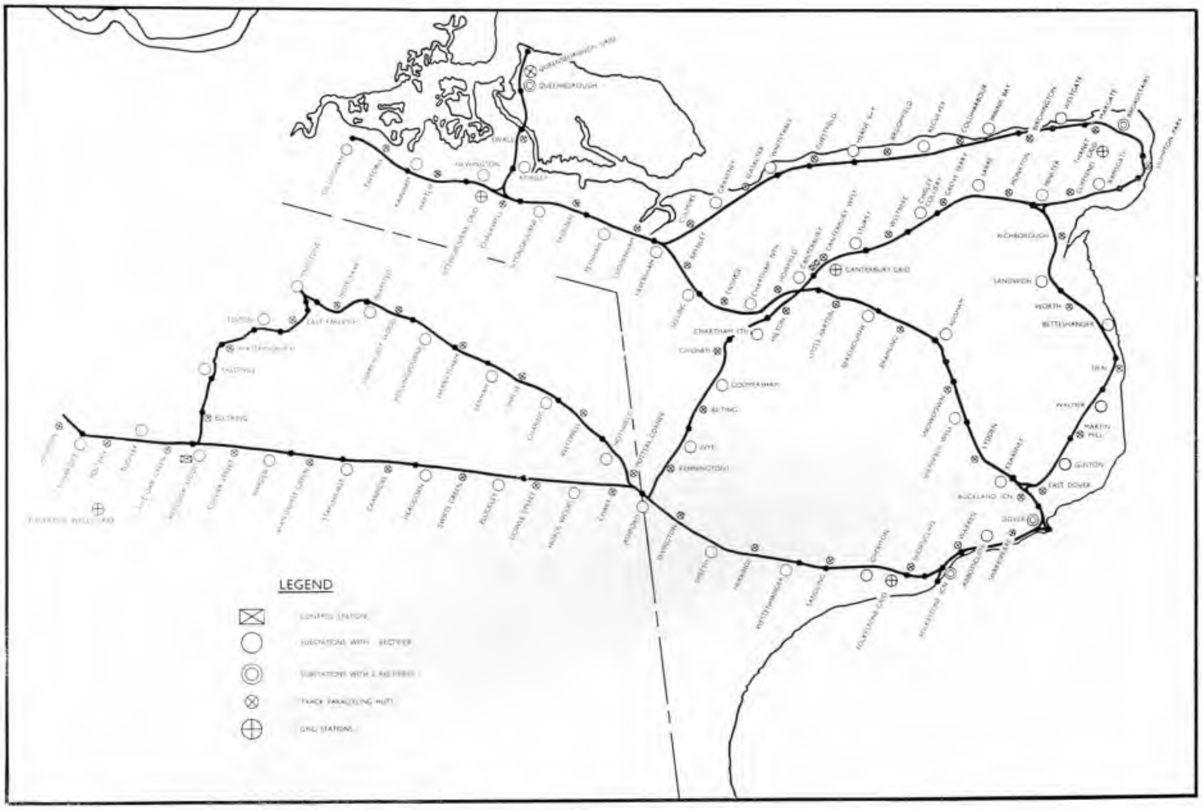

Fig. 1.—Map showing the extent of the supervisory control scheme.

Facilities

The facilities provided by the remote-control equipment are :—

- Control and indication of 33kV feeder oil circuit breakers (O.C.B.'s) in grid stations.
- Control and indication of 33kV feeder and bus section O.C.B.'s in railway substations.
- Control and indication of rectifier a.c. O.C.B.'s.
- Indication of rectifier d.c. high-speed circuit breakers (H.S.C.B.'s).
- Control and indication of track feeder H.S.C.B.'s.
- Indication of bus alive from certain substations and T.P huts.
- Indication of substation common alarm (comprising 50V battery charge fail, 110V battery charge fail, rectifier fault, Buchholz alarm).
- Indication of low oil pressure in oil-filled cables.
- Control and indication of track-paralleling hut H.S.C.B.'s.
- Control and indication of lock out of track-paralleling hut H.S.C.B.'s.
- Indication of substation d.c. busbar voltage.
- Indication of rectifier load in amperes.
- Indication of a.c. feeder volts from substations with grid infeeds, and from Ashford substation.
- Indication of synchronism between two a.c. feeder voltages.
- Indication of average load on each grid feeder
- Indication of a substation in alarm.
- Indication of supervisory faults.
- Indication of supervisory pilot-cable faults.

Communication

Communication facilities are provided

- Between control station and control stations in other areas.
- Between control station and the traction substations and T P huts controlled from that control station.
- Between control station and grid stations feeding into the area.
- Between control station and grid control room.
- Between control station and railway traffic-control office.

Canterbury Control Station

The control station is a single storey building with the control room (Fig. 2) situated centrally and built higher than the other rooms. The walls above the roofs of the adjacent rooms are built of glass bricks in order to provide good natural lighting of the mimic diagram panel and engineer's desk.

Apparatus rooms on either side of the control room house the supervisory control equipment apparatus cubicles (Fig. 5). Behind each apparatus room is a service room in which the pilot cables are terminated and the line-protection equipment is fitted. Battery chargers for the 50V supervisory equipment batteries and the 180V selective ringing telephone battery are also accommodated in the service rooms.

Two 50V batteries and the 180V telephone signalling battery are housed in the battery room behind the control room. The supervisory apparatus in each apparatus room can be connected each to a 50V battery or all apparatus can be connected to either battery.

A plan view of Canterbury Control Station, Fig. 3, shows the control supervisor's office, the track and cable inspector's office and other rooms used for the telephone switchboard, workshop, staff, garage, and heating and ventilating plant.

Mimic Diagram

The mimic diagram, 33 1″ long and 7′ 7″ high, shows the high-voltage feeder system, rectifiers and track feeders controlled from the control room. The face of the control panel is finished matt eau-de-nil with the 33kV feeders as white lines and the 750V d.c. feeders as red lines for up tracks and blue lines for down tracks. The 750V d.c. busbars at substations and T.P huts are shown as yellow lines. Sidings are shown as traffic yellow lines.

The face of the panel is built up of 22″ square panels above a 3″ black kicking panel. The end panels, back, and a thin strip framing the top of the cubicles are finished light grey. The panels are fitted to the front of cubicles 3 8″ wide. A general view of the diagram can be seen in Fig. 2 and a close up view of a section of the panel is shown in the Frontispiece.

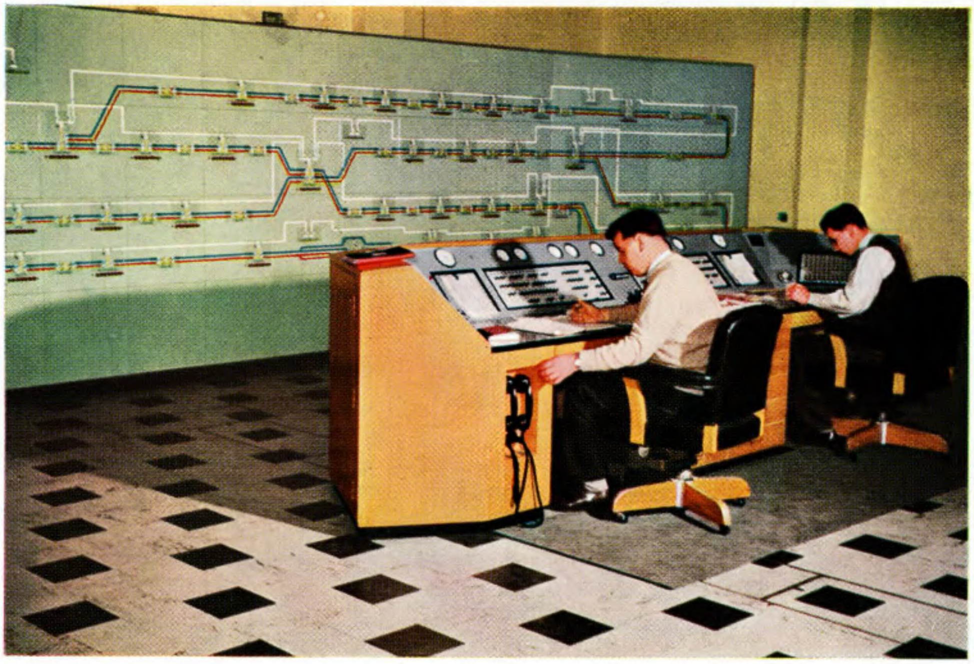

Fig. 2.—Canterbury control room.

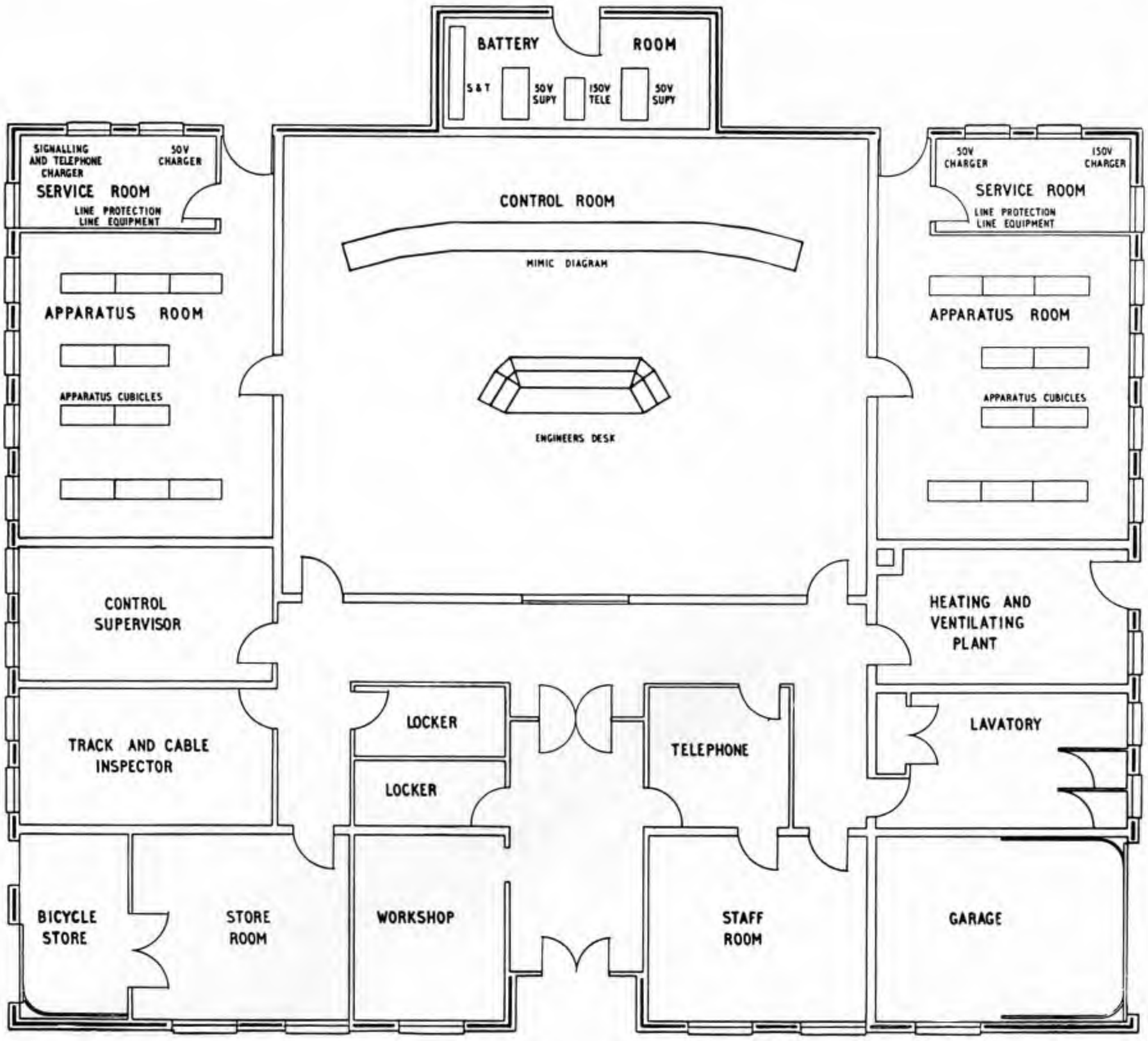

Fig. 3.—Layout of Canterbury control station.

The high-voltage feeder oil circuit breakers, rectifier oil circuit breakers, and rectifier and track high-speed circuit breakers are represented by discrepancy keys, which can be mounted on 1″ centres. The discrepancy-key handles are arranged to complete or break the feeder lines. A $\frac{1}{4}$″ diameter lens in the high-voltage line is illuminated to indicate a low oil-pressure alarm. A substation common alarm is indicated by the illumination of a $\frac{1}{2}$″ lens situated beside the rectifier O.C.B. key. Each substation is provided with its own set of common control pushbuttons arranged beneath the substation name label.

The panel is said to be "dressed" when all discrepancy keys represent correctly the condition of the switchgear concerned and there are no alarms. In this condition the panel is completely "dark"

The discrepancy keys are arranged on a one inch module and additional keys can be added if and when required. For a change involving positional changes of the discrepancy keys a complete new 22″ panel may be fitted in place of an existing panel. When necessary the diagram may be extended by as many additional cubicles as can be accommodated in the control room.

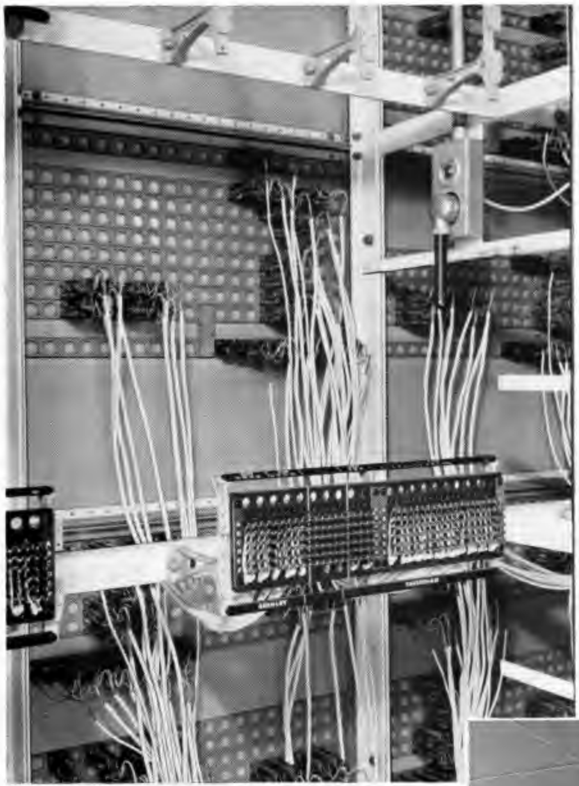

Fig. 4.—Connexions at rear of mimic diagram.

Engineer's Desk (Fig. 6)

The engineer's desk provides sitting accommodation for the control operator and his assistant and houses telephone, metering and alarm panels. The desk is constructed of oak and has a light-oak matt finish. The working surface and the sloping surface housing the meters and key panels is covered with grey "Warerite"

Two telephone handsets are fitted in a recess in each wing of the desk. The outer handsets are connected direct to the Electrification P.B.X. and the inner handsets are used in conjunction with the cordless switchboard fitted in the left-hand wing of the desk.

Connexion can be made from either operator's handset through the cordless switchboard to any substation, T.P hut or grid station in the controlled area, to the supervisor's office, to other control rooms, and to the apparatus rooms. Interconnexion between any of the above sites can be set up by the operator. Two conversations can take place simultaneously.

Access to the key wiring is by hinged double doors at the rear of each cubicle. Each key is wired separately to the terminals at the rear of the cubicle to allow any key to be withdrawn completely to the back of the cubicle for maintenance purposes , this is illustrated in Fig. 4.

When permission is given to work on a circuit breaker at a substation, the discrepancy-key handle representing the breaker on the mimic diagram is covered by a translucent plastic shield clipped to the bezel round the key. This allows the state of the breaker to be seen but prevents the key being operated.

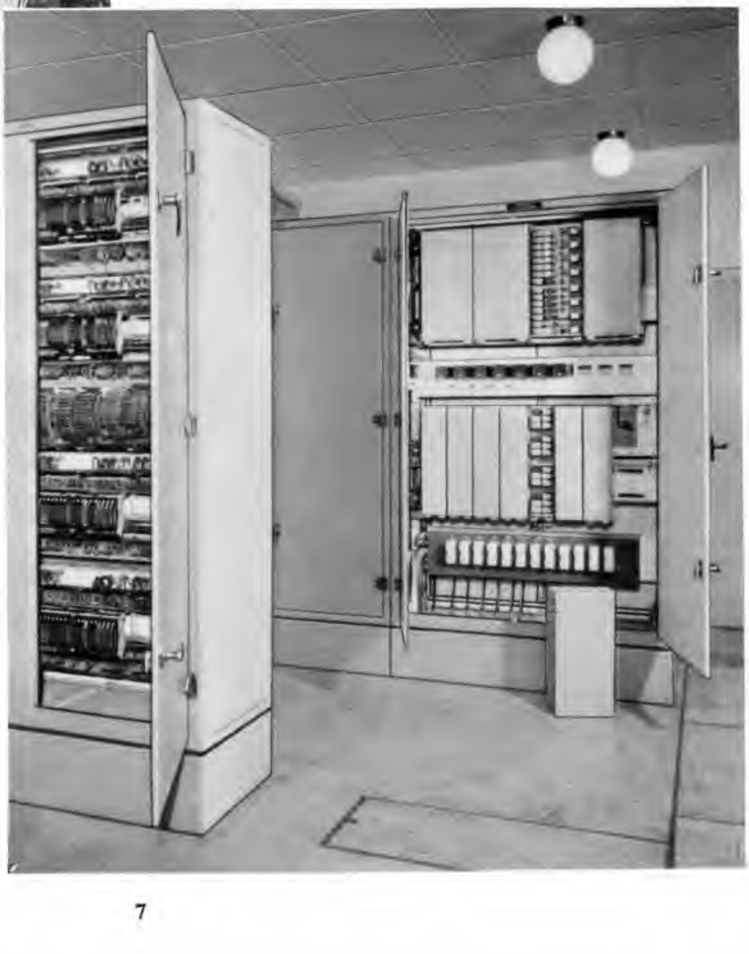

Fig. 5.—Control station apparatus room.

Either operator can be connected to Orpington traffic control office and to the local grid P.A.X. Interconnexion between either of these two lines and any others is barred.

Meter-selection key panels, meters and clocks in duplicate are accommodated in the centre sloping panel. The meters and selection keys for substation volts, rectifier amperes, feeder load in megawatts from grid inputs and a.c. volts from incoming feeders are laid out in mirror image arrangement on either side of the frequency meter and a calendar is fitted in the centre of the panel. Two lamps mounted on the rear of the desk for easy viewing from the diagram are used to indicate when the voltages of two incoming feeders are in synchronism.

The right-hand wing of the desk houses the key and lamp panel for pilot and supervisory alarms, and the substation-in-alarm indicator. A lamp is provided for each tandem system equipment, for each system pilot, and for each substation equipment. Other lamps are used to indicate a blown fuse, charger fail, and earth leak.

Hinged doors at the rear of the desk provide access to the terminal strips, keys and relay set, which is fitted with the relays common to all the supervisory equipment. Two drawers in the desk are sectionalised for folders to take the "Permit to Work" slips. A further eight drawers are provided for the use of the operators.

Apparatus Cabinets (Fig. 8).

The relay and selector apparatus is housed in double-walled all-steel cabinets fitted with hinged doors at the front and rear. The cabinets, 6′ 3″ high, 4′ 0″ wide and 1′ 6″ deep, are flexibly mounted on a 9″ high stool to prevent vibrations from trains running near the control room affecting the relay operation.

One cabinet in each apparatus room houses a 50V battery distribution panel, the telephone and feeder load metering relay equipment, and a relay set fitted with the relays common to the apparatus room equipment.

The remaining apparatus cabinets in each apparatus room are all similar, each housing the equipment for one tandem system. Two jacked-in relay sets on each of the top two shelves are fitted with the relays common to the tandem system.

Fig. 6.—Engineer's desk.

Fig. 7.—Line-protection equipment.

The first relay set on each shelf is fitted with relays common to a substation, and the remaining relay sets on each shelf are fitted with the point relays for that station. Between the two top and the two bottom shelves a framework carries the point uniselectors for each substation, uniselectors common to the tandem system and the high-speed polarised line relays.

A telephone jack in each cubicle allows for a telephone to be plugged in for maintenance and testing purposes.

Line-Protection Equipment

Line-protection equipment, Fig. 7, consisting of gas-filled protectors for the supervisory-control pilots and carbon-block protectors and fuses for the telephone lines, is housed in wall-mounting steel cabinets fitted in close proximity to the pilot-termination boxes in the service rooms.

Cabling

Interconnexion between the wall diagram, desk and apparatus cubicles is by multicore PVC-insulated and lead-sheathed cable run in ducts in the control-station floor. All cables were supplied by Pirelli-General Cable Works.

Substation Equipment

The substation relay and associated apparatus is accommodated in double-walled steel cabinets 6′3″ high, 2′ 6″ wide and 1 6″ deep, fitted with hinged doors front and rear (Fig. 9). The cabinets are flexibly mounted on 9″ high pedestals to damp out vibrations from passing trains.

Relays are fitted on jack-in plates for ease of maintenance. The substation common relays are fitted on two jack-in mountings. The remaining relay sets in each substation are fitted with the point relays for the particular requirements of that substation. The wiring of all substations is similar except that the outlets from the point selectors follow four variations which cater for different quantities of substation and satellite points to be controlled.

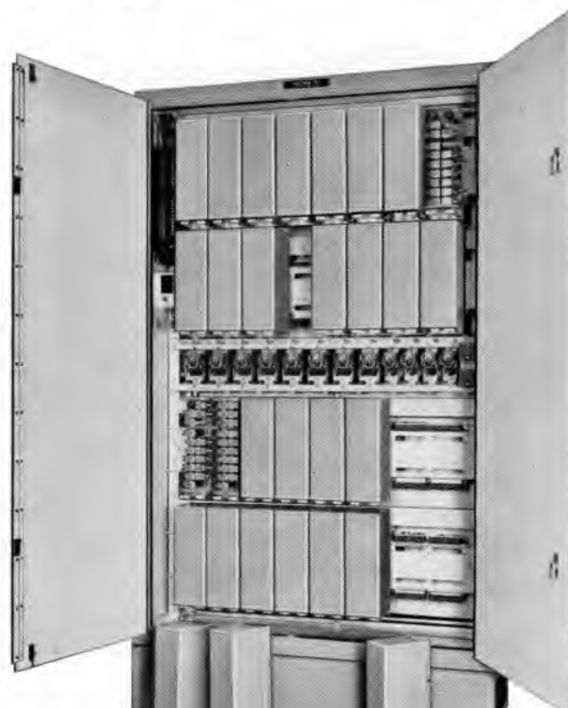

Fig. 8.—Control station apparatus cabinet.

Variable line-padding resistors and line-terminating equipment are fitted at all substations so that any substation can become a terminating substation should a pilot cable be accidently cut on a route.

A telephone connected to the selective-ringing telephone system is fitted to the side of the apparatus cubicle.

Line-protection equipment is housed in a steel wall-mounting cabinet.

For ampere-load metering from each rectifier, a transductor is fitted on the relay panel and connected to a shunt in the negative feed.

A volts transductor, together with fuse and dropping resistor, is mounted on the wall at the end of the d.c. busbars for substation-voltage metering.

At substations where H.V feeder voltage is to be metered, an interposing voltage transformer is fitted on the associated O.C.B. panel.

All switchgear wiring is terminated in a marshalling box of the same plan size as the supervisory cabinet and suspended immediately above it. Interconnexion between the supervisory cabinet, marshalling box, line-protection equipment and pilot-termination box is by multicore PVC-insulated and sheathed cable.

The floor plan of a typical substation is shown in Fig. 11

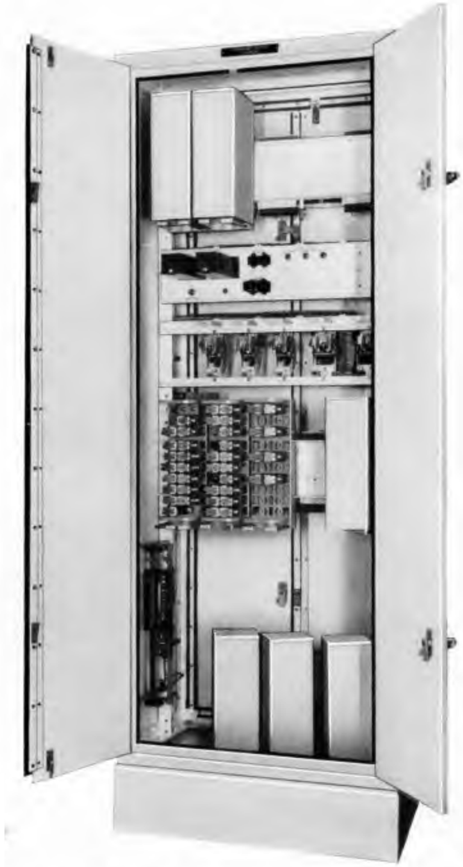

Fig. 9.—Substation apparatus cabinet.

Fig. 10.—Typical substation.

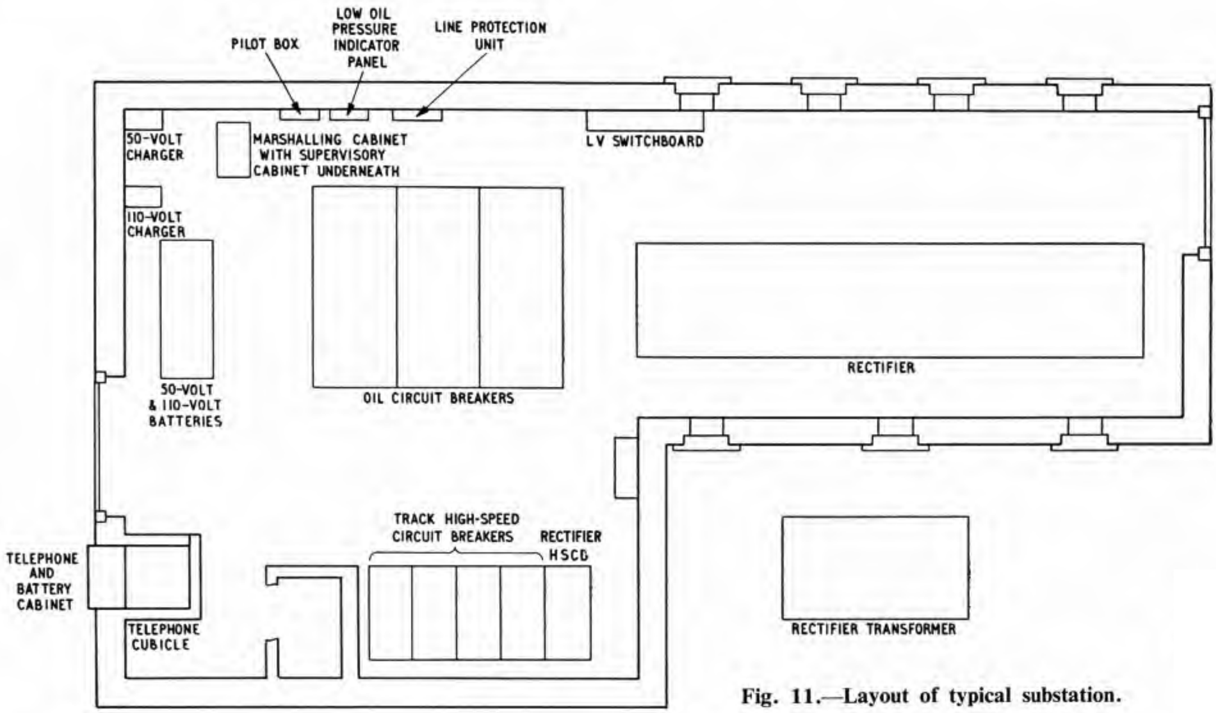

Fig. 11.—Layout of typical substation.

Track-Paralleling Hut Equipment (Fig.14)

The quantity of relay equipment required at a track-paralleling hut is small and is mounted on jack-in relay sets housed in a steel wall-mounting cabinet, which also contains the marshalling terminals for the switchgear connexions. One relay set is required for each two H.S.C.B.'s and the cabinets are made in two sizes, one for track-paralleling huts with up to four H.S.C.B.'s and the other for track-paralleling huts with five to eight H.S.C.B.'s.

A selective-ringing telephone equipment is mounted on the wall adjacent to the supervisory-control equipment cabinet.

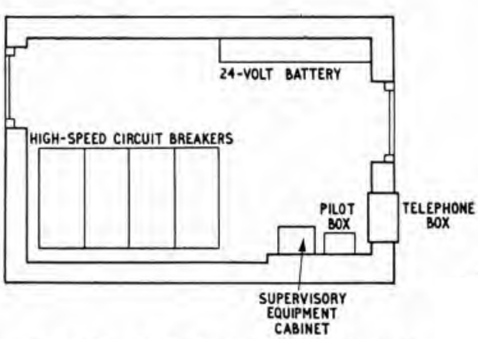

Fig. 12. Layout of typical T.P hut.

The H.S.C.B. interposing relays are operated from a 24V battery, which is charged over pilot cores from an adjacent substation.

The layout of equipment in a typical T.P hut is shown in Fig. 12.

Grid-Station Equipment

Similar equipment to that fitted in track-paralleling huts is fitted in C.E.G.B. stations in which feeder breakers are remotely controlled. The steel wall-mounted cabinets contain jacked-in relay sets and marshalling terminals. The O.C.B. interposing relays, supplied by the G.E.C. are operated from the 50V substation battery at the substation on which the grid station is satellited.

A central-battery desk telephone instrument at each grid station is connected direct to the control station.

Contacts of the feeder kilowatt-hour meter of the O.C.B. controlled are connected via the marshalling terminals to the pilots for feeder-load metering at the control station.

Supervisory-Control Tandem Systems

The control of all substations in one area is by means of a number of supervisory-tandem systems, each system controlling up to four substations. The adjacent substations on a route are connected to different tandem systems. The H.S.C.B.'s in a track-paralleling hut are satellited on the adjacent substations, each substation controlling the H.S.C.B.'s of tracks running towards the next substation on the route. Should a pilot-cable failure put one system out of action, the track can still be completely electrified by the control of every other substation and half the H.S.C.B.'s in the T.P huts from the second tandem system on the route.

As a further guard against complete failure of control, the control-station apparatus for two tandem systems controlling the substations on a route is housed in separate apparatus rooms. Fig. 13 shows the connexion of substations and T.P huts to the supervisory systems on a typical route.

Figs. 15 and 16 show block schematic diagrams of a tandem system, and of a metering and telephone system, respectively.

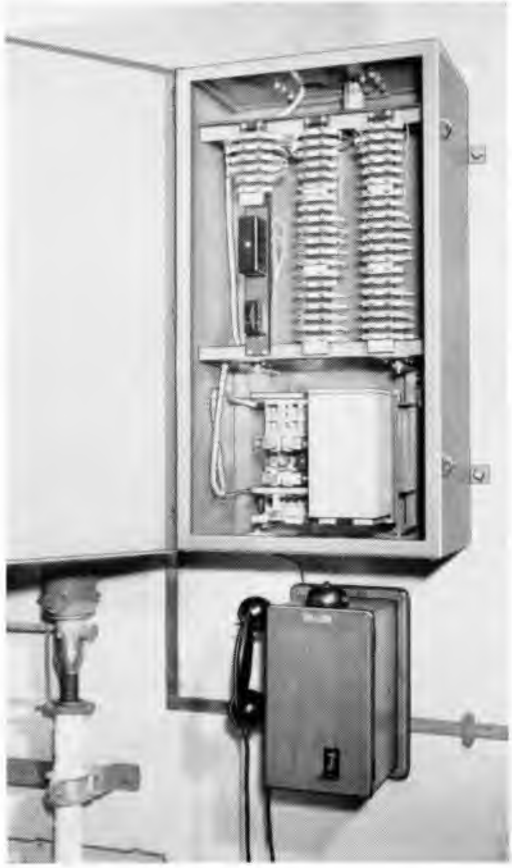

Fig. 14.—T.P hut supervisory-control equipment.

Operation

Principle

The remote control and indicating system used is known as the "check-back" type, the term "check-back" being derived from the fundamental principles employed by the circuit.

In such a system, a train of pulses is transmitted to the distant end and counted at both sending and receiving ends. A train of pulses equal in number to the original transmission is then sent back from the distant end to the sending end. These pulses are again counted at both sending and receiving ends. Only when the numbers of pulses exactly coincide at each end is the control or indication proceeded with.

Fig. 17 shows simply how this is achieved, when CK is operated at the control station and SK is operated at the substation, the check back is complete at both ends.

This is a very simplified description of the system, but serves to illustrate the check-back principle.

The system is basically a four-wire tandem system, with two wires handling the pulsing transmitted from the control station outwards, and two wires handling information sent into the control station from the substations. Up to four substations can occupy a tandem system. More than four wires per tandem system are actually used, two more wires per tandem system being provided in order that a "substation in alarm" indication can be given when the common circuits are engaged. Remote indication of a.c. volts and check synchronising from certain substations occupy two more wires from the substations offering this indication to the control station.

As up to four substations are connected in tandem, the line relays at each substation in a system respond to pulsing from the control station. To ensure accurate impulse repetition by these line relays, forward and reverse pulses are used with high-speed polarised relays in the line at each substation and the control station. Whilst no intelligence is contained in the polarity of the outward pulsing from the control station, intelligence is contained in the polarity of the pulsing from the substation. This will be more fully explained later, the terms forward and reverse being only relative.

Up to 44 controls and/or indications can be accommodated at any one substation.

Since there are possibly four substations on any one tandem system, each substation must be positively identified before a control or indicate cycle can select the required point.

The substation identity is defined at the sending end, that is, at the control station for control cycles, and at the substation for indicate cycles. Uniselectors are used as pulse counters and up to eight pulses are required to identify any substation. Check back takes place at the end of substation selection and at point selection. Fig. 18 shows how check back is developed for these requirements.

Control Cycle: Substation Selection

When a control cycle is initiated, a mark is put on a bank outlet of the substation send selector at the control station, and pulses are sent simultaneously to all the substations on the tandem system. These pulses are counted at the substations on a substation receive selector and at the control station on the substation send selector The pulses continue until the substation send selector meets the marked outlet. Since this train of pulses is counted at all substations on a tandem system, the wanted substation is identified by the number of pulses transmitted from the control station. When the wanted substation has been identified, a pause in signalling is introduced and the substation sends back to the control station the number of pulses it has received, the counting of both transmitted and received pulses at each end constituting the check back. A seizing pulse, common to all substations on a tandem system, plus two more pulses are required to select the first substation, and multiples of 2 pulses for other substations, up to the maximum of 8 pulses for the fourth substation.

A pulse is approximately 100ms long and consists of 50ms forward current and 50ms reverse current.

Indicate Cycle: Substation Selection

This follows a similar pattern to the control cycle. The substation selectors at the control station are made to search for the sending substation until a stop signal, originated at the substation, is encountered. An identical train of check-back pulses is sent after the substation has identified itself.

Indication of Substation Points

When a substation point changes state, a "start signal" is transmitted to the control station over the third pair of pilot wires, which is otherwise used for the "substation in alarm" indication previously mentioned. This causes the control station to search for the sending substation in the manner described and seize the points selectors at the substation and the appropriate points selectors at the control station. The points selectors then proceed to

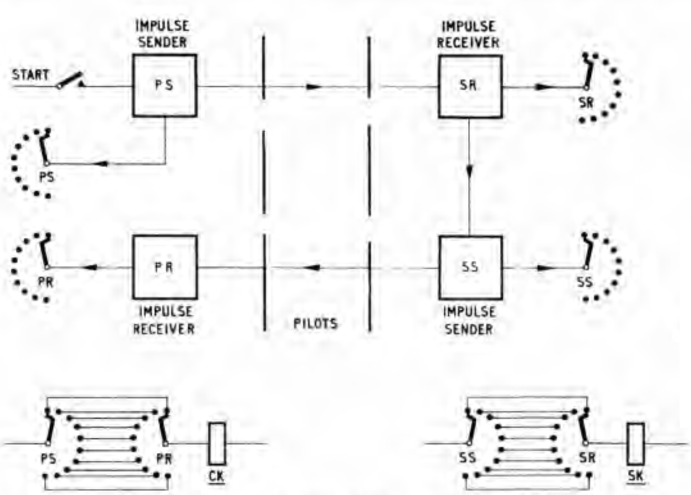

Fig. 17.—Principle of check-back method of operation.

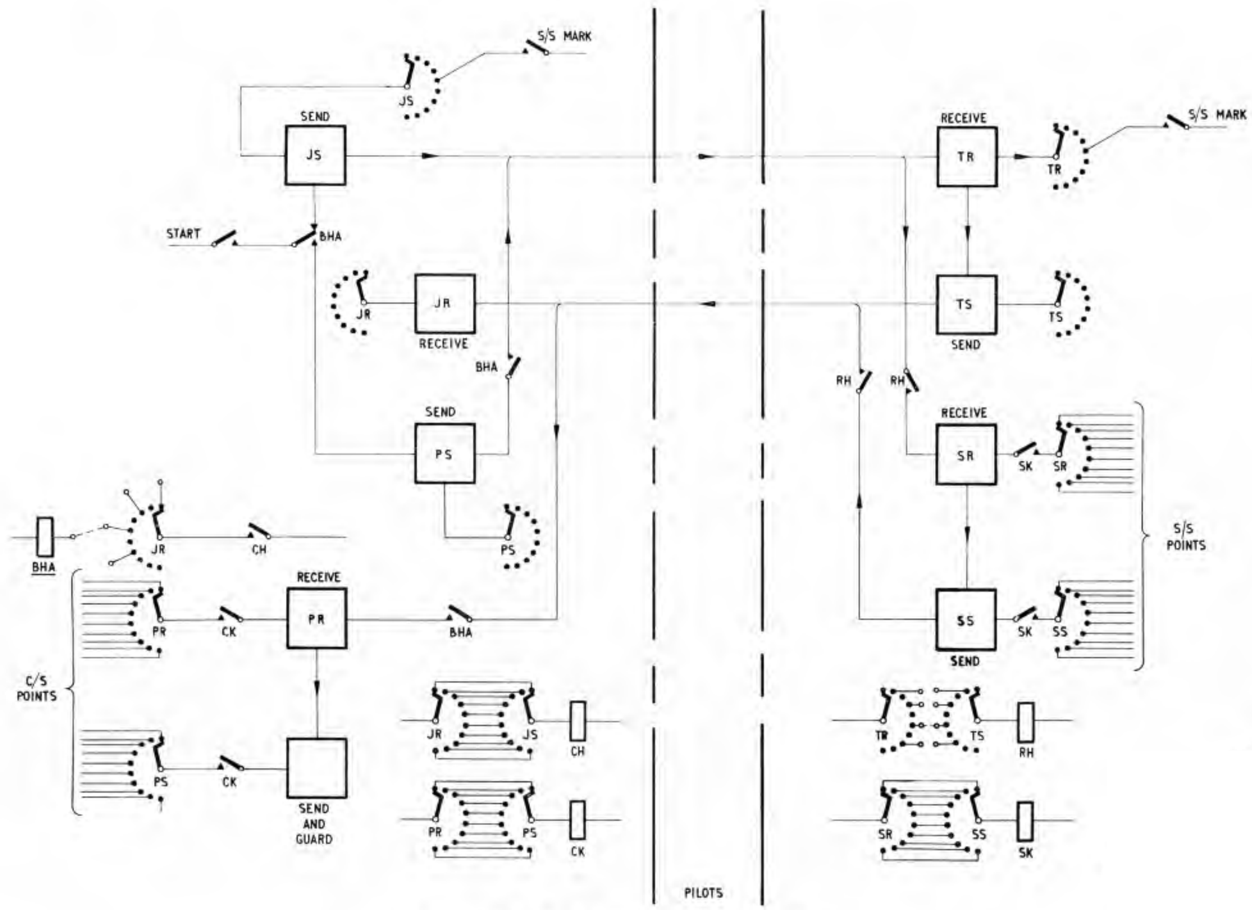

Fig. 18.—Check-back from a substation.

examine all the points at the originating substations to discover any change, checking back to the control station at each point and before any change is actually indicated. A change of indication originated from the substation is given by an audible alarm and the flashing of the substation nameplate lamp and discrepancy-key lamp associated with the changed point. "Dressing" the diagram by turning the discrepancy key through 90°, silences the alarm bell and extinguishes the flashing lamps. A "stop alarm" key is provided on the wall diagram to silence the bell and extinguish the substation nameplate lamps should the control operator not wish to dress the diagram immediately. Alarms not directly associated with track supply, e.g., "substation alarm", which means that attention is required at that substation, are indicated by a flashing lamp and an alarm bell on the desk. A "stop alarm" key is provided on the desk to silence the bell and steady the flashing lamp.

A feature of both these "stop alarm" keys is that the bell is silenced on operation of the key and the alarm is accepted on the release of the key.

As all the substation points are in one of two states, e.g., a circuit breaker is either open or closed, only two signals are required. In practice a pulse of forward current is transmitted to the control station for the open state and one of reverse current for the closed state. If a change is detected, the points selectors cannot move off that point until either the point relays at the control station have been aligned with the substation points or, if this is impossible due to, say, a dirty auxiliary contact on a circuit breaker, a fault has been indicated.

When the points selectors arrive at outlets, which, for any reason, are unequipped, they cease checking back at each point and proceed rapidly to the next point that is equipped where the check back again takes place, and examination of the points continues. When all the points contained in the particular substation have been examined in this way, the circuits restore and become available for further use.

Control of Substation Points

This takes place in three separate but allied stages

Selection of wanted substation.
Selection of wanted point.
Control of selected point.

To select the wanted point, the discrepancy key is turned into the discrepancy position. The selection of the wanted substation takes place as already described. The discrepancy key puts a mark on the wanted outlet of the points selector at the control station and causes the lamp in the centre of the handle of the discrepancy key to flash. The points selectors at both the control station and the substation rapidly search for the marked point with the control selectors always slightly ahead. Immediately the mark is found, the control selectors stop and, as soon as the check-back pulses from the substation equal the number of pulses transmitted from control, the substation points selectors stop. In this way the wanted point is selected as quickly as possible.

Check back is now complete and the substation point transmits a continuous current of either forward or reverse flow according to the state occupied by the point. At this stage the lamp in the discrepancy key glows steadily and remains in this state during the time that the equipment is parked on that particular point.

The continuous current returned from the substation indicates the state of the selected point and illuminates either the "open" or "close" operate button. Hence, there is a simultaneous display of which point is selected and the state of that point.

To control the point, a coded operate signal is transmitted by taking over the duty of the high-speed polarised relay at the substation, up to now used for substation and points selection.

The coded operate signal consists of six pulses 1 short, 1 long and 4 short for an open operation and 3 short, 1 long and 2 short for a close operation. In each case this is followed by fifteen 100ms pulses to give a minimum operate signal of 1·5 seconds to the point. This minimum can be over-ridden by the operator and maintained for as long as required.

Immediately the substation point changes state as a result of this control operation, the polarity of the signal returned to the control station is reversed, this is at once sensed by the polarised relays at the control station and the change of state displayed by the illuminated operate pushbuttons. The discrepancy lamp continues to glow steadily as an indication that the equipment remains parked on the point.

It is a feature of this system that the operator can park the control circuits on any desired point and immediately observe any change in the state of that point whilst so parked. There is no limit to such parking on a point, and to move the equipment off, the operator must press the "step-on" button, when the equipment will either select the next wanted point or restore to normal if no further points are wanted. This feature is particularly valuable in a traction supply control system, where circuit breakers are often closed on to a large overload and may trip out again almost immediately. Such an occurance can at once be observed by the operator.

Procedure

The entire system is controlled from the mimic wall diagram and engineer's desk in the control station.

When the handle of a discrepancy key representing a circuit breaker is in line with a diagram line, the circuit breaker is shown closed, and when the handle of the discrepancy key breaks the diagram line, the circuit breaker is shown open. To select the opposite state to that occupied, the discrepancy key is turned into the wanted position.

A row of pushbuttons is associated with each substation on the wall diagram for control purposes, all switching operations being carried out directly from this position.

The metered quantities are selected from and displayed on the engineer's desk, which also accommodates the alarm lamp and key panel, and cordless telephone switchboard.

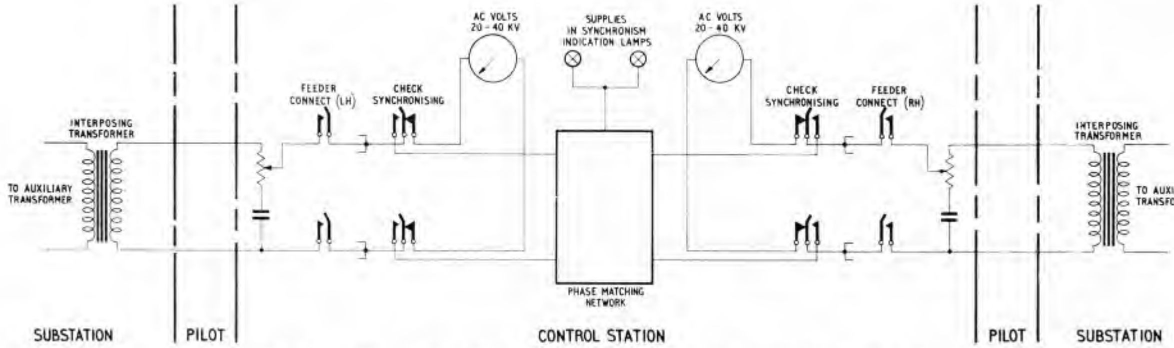

Fig. 19.—Diagram illustrating the checking of two a.c. supplies for synchronism.

Track-Paralleling Huts

If reference is made to Fig. 13, it will be seen that a T.P hut appears between each pair of substations, each T.P hut being satellited on two substations, an associated substation controlling and receiving indications from the T.P hut breakers farthest away from it.

When a track is made alive from a substation, the T.P hut breakers nearest to it will close automatically and will indicate back to the neighbouring substation, which in turn relays the indication(s) to the control station over another tandem system.

The terms nearest and farthest used here only refer to Fig. 13 and not to the actual distance.

A lock-out is associated with each T.P hut circuit breaker to prevent the automatic closing mentioned. The lock-out can be applied and removed as required by the operator quite separately from control of the associated circuit breaker. The lock-out device is shown on the wall diagram by a discrepancy key immediately adjacent to the T.P hut circuit breaker discrepancy key with which it is associated.

C.E.G.B. Supplies

The oil circuit breakers controlling the a.c. intake to the traction system and situated in C.E.G.B. substations are satellited on a railway traction substation in much the same way as the T.P hut breakers are satellited. Control and indication take place via this parent substation.

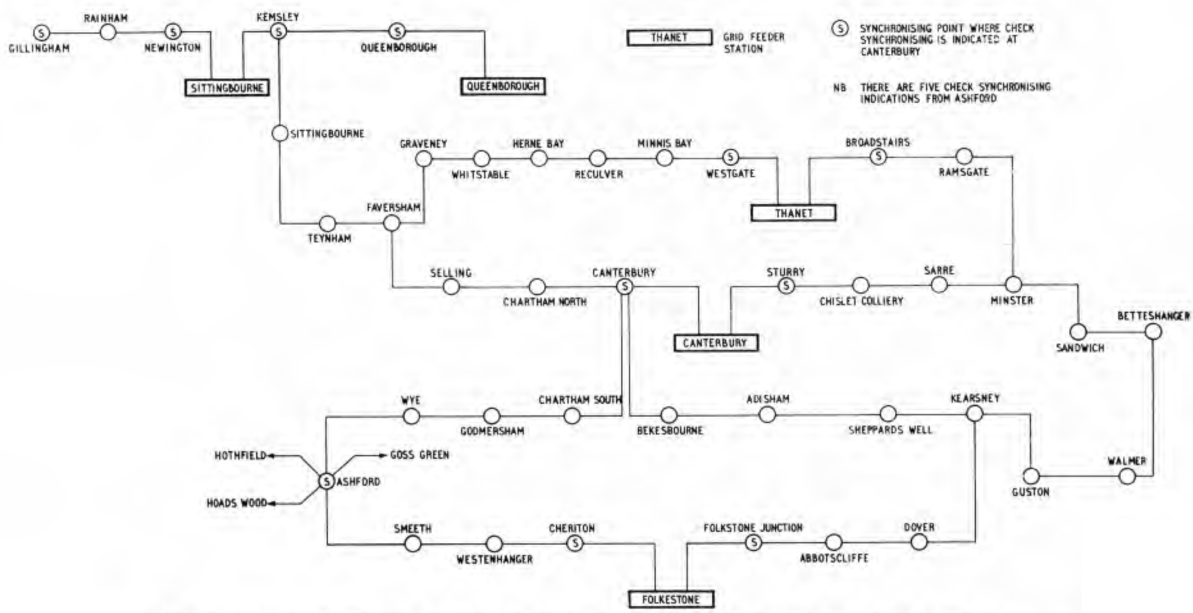

Fig. 20.—System diagram showing stations from which check synchronising is available.

Check Synchronising

When a.c. switching is taking place, it may be that the a.c. intake points are momentarily paralleled via the railway a.c. distribution network. It is therefore necessary for the control engineer to know that these supplies are in synchronism before paralleling takes place. The supplies are therefore brought into the engineer's desk as shown in Fig. 19 and compared. If the selected supplies are in synchronism, the two lamps which initially flash to indicate selection of a.c. volts glow steadily. Paralleling can then take place.

Feeder-Load Metering

Remote indication of high-voltage feeder load is also available from both sides of the engineer's desk and Fig. 21 shows how this is arranged. A contact making W/H meter pulses a counting circuit arranged on a binary basis. At definite time intervals the number of counts received is assessed, and transferred in binary increments or decrements to a constant-load resistance network where the counted quantity is continuously available for display on request. The desk instrument gives the load in megawatts.

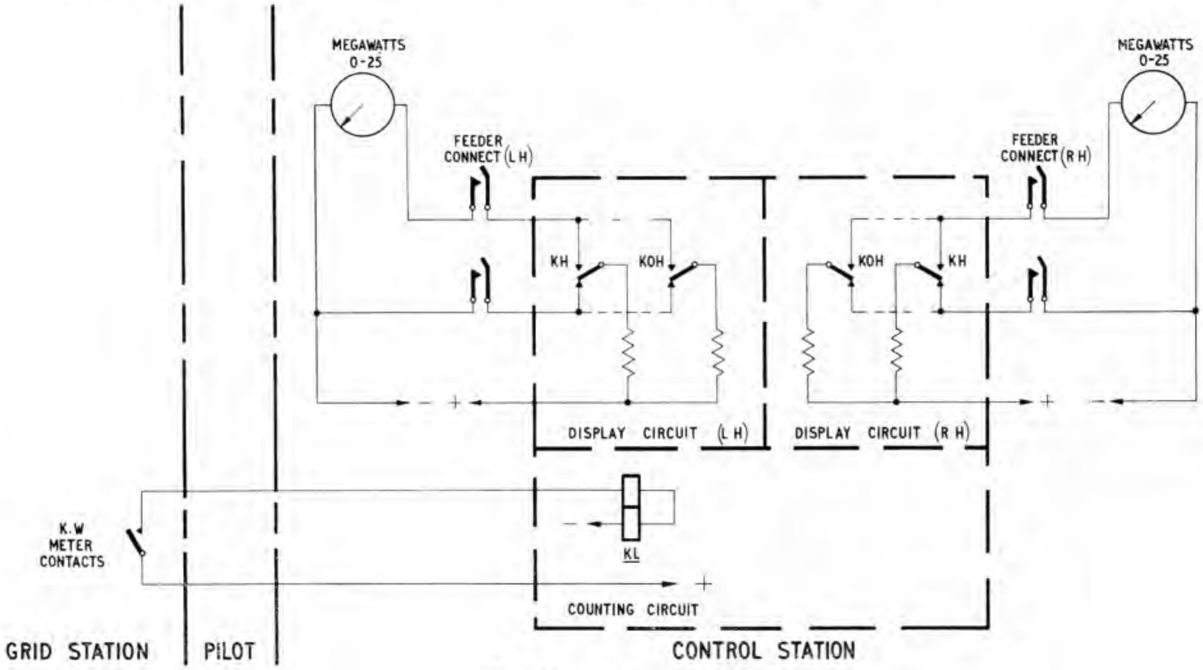

Fig. 21.—Load metering.

As these metered quantities are brought into the engineer's desk over vastly varying distances a simple C/R pad is connected across each a.c. pilot pair so that adjustment for attenuation and phase shift in the pilots can be carried out when the system is installed. Fig. 20 shows a.c. intake points and points from which check synchronising is available.

Metering

A.C. Volts.

The facilities shown in Figs. 19 and 20 also offer remote indication of a.c. volts. This is available by key selection from either the R.H. or L.H. side of the engineer's desk.

D.C. Metering

At each substation there are two self-excited series transductors with d.c. output arranged as shown in Fig. 22. The control winding of one is connected to measure current and the control winding of the other is connected to measure volts. If the d.c. load or bus-bar voltage at a substation is required by the control operator, a select cycle is initiated from the desk. This connects the output of the appropriate transductor on to the pilot pair otherwise used for transmitting points indications back to the control station. The metering quantity is then displayed on the desk and the control circuits restore for further use, leaving the metering on the pilots. If the control circuits are subsequently taken into use the metering is automatically disconnected while the pilots are used for control and/or indication purposes. As soon as the pilots again become free, the metering is automatically re-connected to the pilots and hence the desk meter. To dispense with the metering altogether, the "meter select" key is restored initiating another select cycle to disconnect the transductor

"Substation in Alarm" Indicator

Due to the "park on a point" feature of the control circuits, it is desirable that the control operator has the facility of determining the location of any substation(s) in an occupied tandem system that are waiting to send information into the control station.

For this purpose a "substation in alarm" indication is provided on the R.H. side of the engineer's desk (see Fig. 23).

If a substation in a tandem system occupied for control purposes comes into alarm, it is indicated on the wall diagram by the flashing of the L.H. substation nameplate lamp. The operator can then go to the desk and, by throwing a tandem system connect key, apply the "substation in alarm" indicator to the busy tandem system and thereby determine precisely which substation(s) are waiting to send information into control. It is then left to the discretion of the operator which function, control or indication, is allowed to proceed.

Check Request

The facility is provided for a check request to be transmitted to any substation in the system. Receipt of this signal causes the point selectors to examine and check the alignment of all the control-station point relays with the actual substation points, any discrepancy

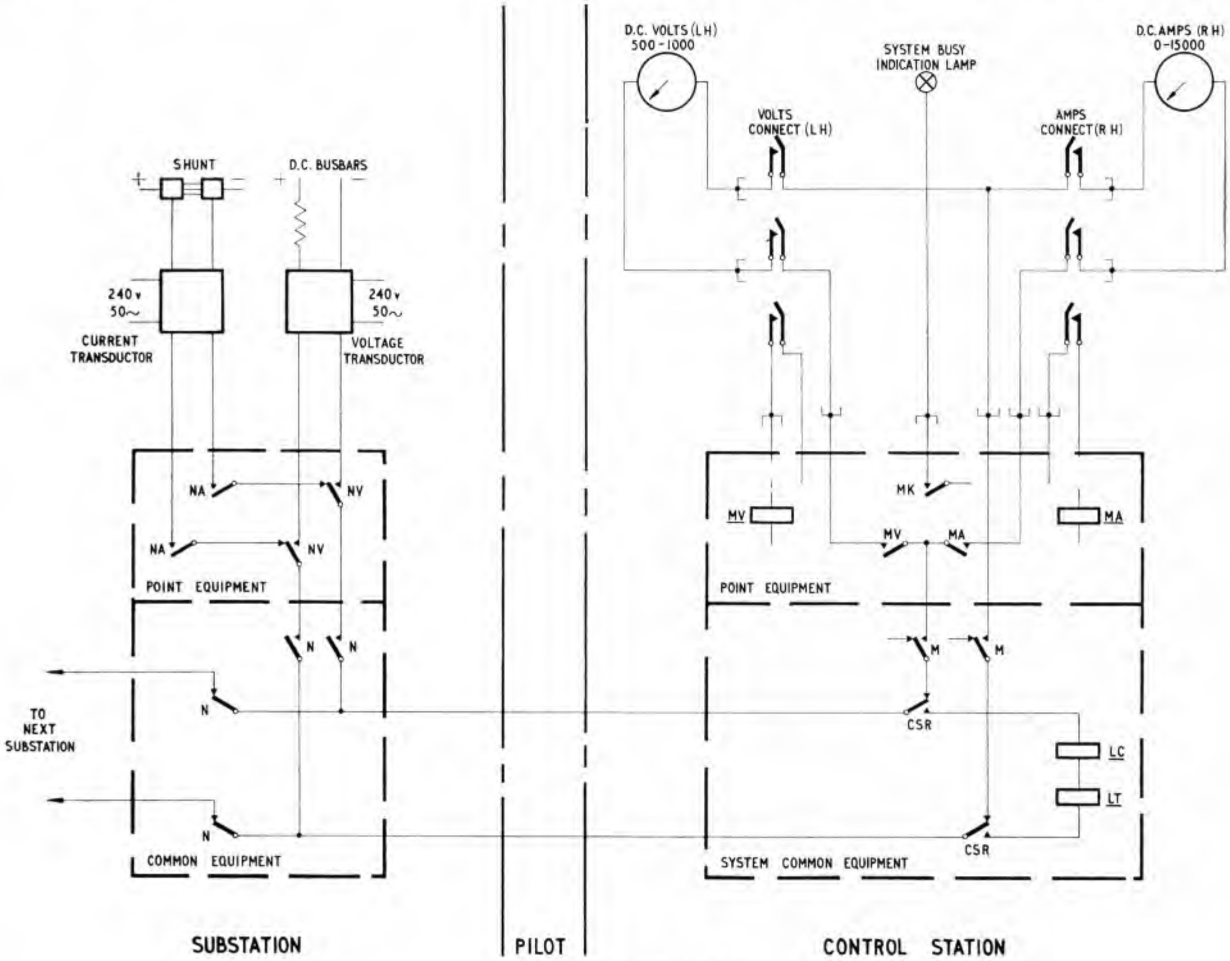

Fig. 22.—D.C. metering.

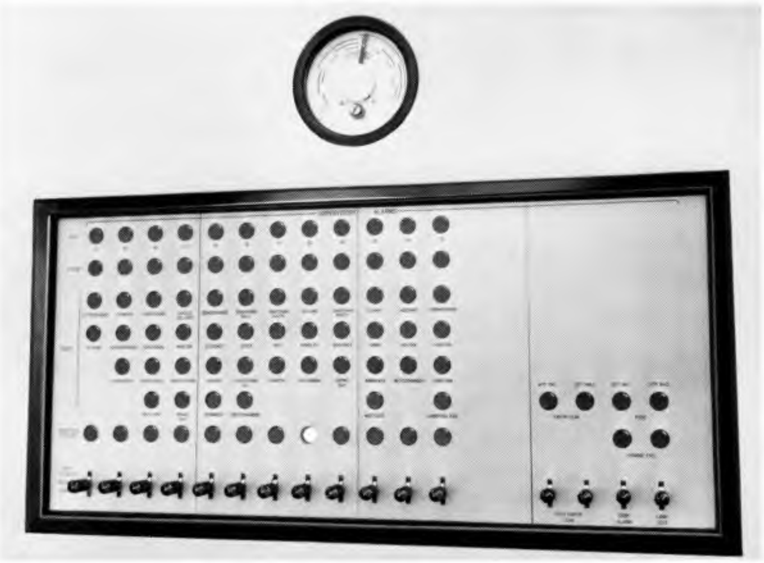

Fig. 23.—Substation in alarm indicator.

being indicated by the flashing of the discrepancy lamp for that particular point. At the completion of a satisfactory check of the substation points the check lamp, which has flashed throughout the cycle, is extinguished and the control circuits restore for further use.

Maintenance

Line Test

Each pilot pair of all tandem systems is continuously tested for open circuit, short circuit, and earth leakage. If any of these fault conditions occur it is indicated on the operator's desk by means of a flashing lamp and audible alarm.

Fuse Alarm

All fuses are of the alarm type giving an audible and visual alarm when blown. A beacon lamp is also illuminated on the apparatus cubicle containing the blown fuse.

General

The system has been engineered to keep maintenance and spares to the least possible amount, and to assist in the rapid location and correction of any fault.

The equipment has been divided into two apparatus rooms and, operationally, the system could suffer the loss of the whole of the equipment contained in one of these rooms. The remaining equipment in the other apparatus room would still enable the complete traction system to be operated.

Acknowledgment

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References

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2. G.E.C. Journal, Vol. 21 No. 4, p.199, October, 1954