THE

STROWGER JOURNAL

Vol. III. No. 2. MARCH, 1935

ARTICLES IN THIS ISSUE:

AUTOMATIC ELECTRIC COMPANY LTD.

STROWGER WORKS, LIVERPOOL, 7

Telephone: Old Swan 830. *Telegrams: "Strowger," Liverpool.*

MELBOURNE HOUSE, ALDWYCH, LONDON, W.C.2

Telephone: Temple Bar 4506. *Telegrams: "Strowger Estrand," London.*

THE NORTH-WEST AND SOUTH-WEST OF ENGLAND GRID SIGNALLING SYSTEMS

By T. R. RAYNER, *Transmission Engineer, and* G. A. BURNS, *Development Engineer,*
Automatic Electric Company Ltd., Liverpool.

SYNOPSIS.

Maps are given showing the areas covered and the disposition of the various stations on the two sections of the "grid," and views of the central indicating stations at Manchester and Bristol are included. Schematic diagrams of the line circuits and apparatus for the various classes of signals are given and described, including circuit-breakers, transformer tap-change switches, metering, "Inter-tripping" of circuit breakers and tandem working. Views are also given of typical installations of the signalling apparatus at various stations.

The maps, Figs. 1 and 2, show the disposition of the North-West and South-West of England "Grid" signalling systems respectively. The central indicating and control station for the North-West "grid" is located in Manchester, whilst that for the South-West "grid" is situated in Bristol. The signalling and controlling facilities provided on these grid sections are in general similar to those provided on the Central Scotland grid, descriptions of which were given in two previous issues of the STROWGER JOURNAL, namely, Vol. I, No. 1, and Vol. II, No. 2. The two recent equipments are, however, characterised by various simplifications in the arrangement of the apparatus and also by some additional and new features, which have been incorporated.

On each of the N.W. and S.W. "grids," for example, local subsidiary systems at certain generating stations are provided for the supervisory remote control of the adjacent grid sub-station. On these grids the important feature of "inter-tripping" of circuit breakers is also provided for. This latter feature is described at some length later. Tandem working, whereby the signals from two stations are transmitted over the same pair of wires without mutual interference, is also employed in the case of certain of the more outlying stations.

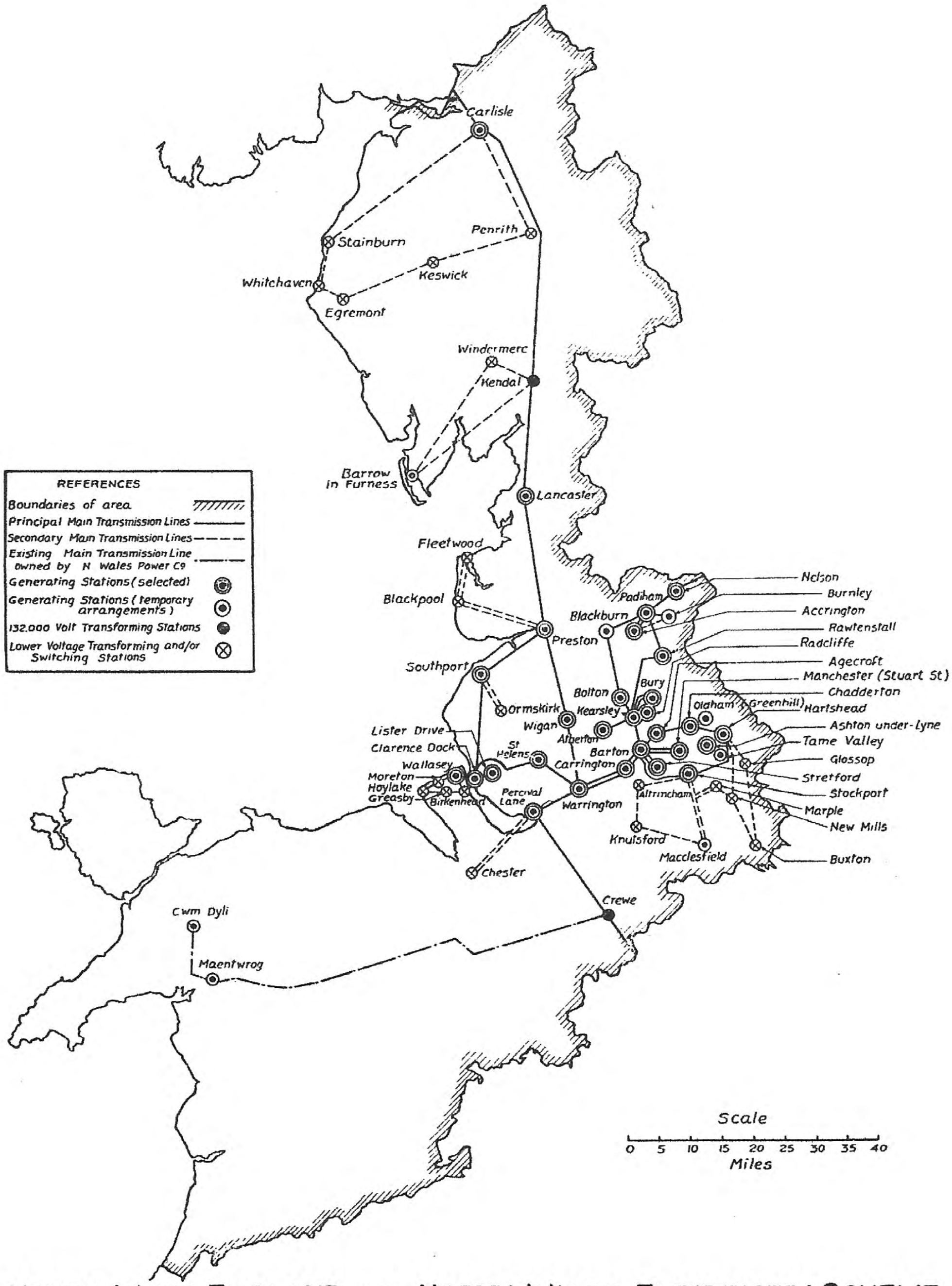
In order that tandem working can be provided, four frequencies are required, the frequencies employed being 1500, 1250, 350 and 300 cycles, as against three frequencies, namely, 1440, 576 and 288 cycles, employed on the Scottish "grid." In the case of the latter the three frequencies are generated by rotary machines, and filters are employed in the line circuits in conjunction with thermionic amplifier receivers, in the plate circuit of which telephone relays are inserted. On the other hand, in the case of the N.W. and S.W. "grids" the four frequencies are generated by valve oscillators at the outlying stations and by constant speed generators at the central indicating station. The frequencies being therefore practically constant under all conditions, "resonant" circuits are used in conjunction with the thermionic receivers. These modifications provide improved impulsing characteristics.

On the N.W. and S.W. "grids," various simplifications in the signalling apparatus have also been effected. These include the substitution of a uniselector at each outlying station for four circuit breakers instead of an individual relay per circuit breaker, and also a uniselector per transformer instead of a set of fifteen relays, one of which was associated with each tap switch position.

At the central indicating stations the magnetic locking type of relay has been substituted for the latching type of relay. The specially rapid method of remote metering, termed "contact" metering, has also been incorporated and enables "spot" readings of all the meters on one station to be taken in succession at the rate of about twelve meters per minute.

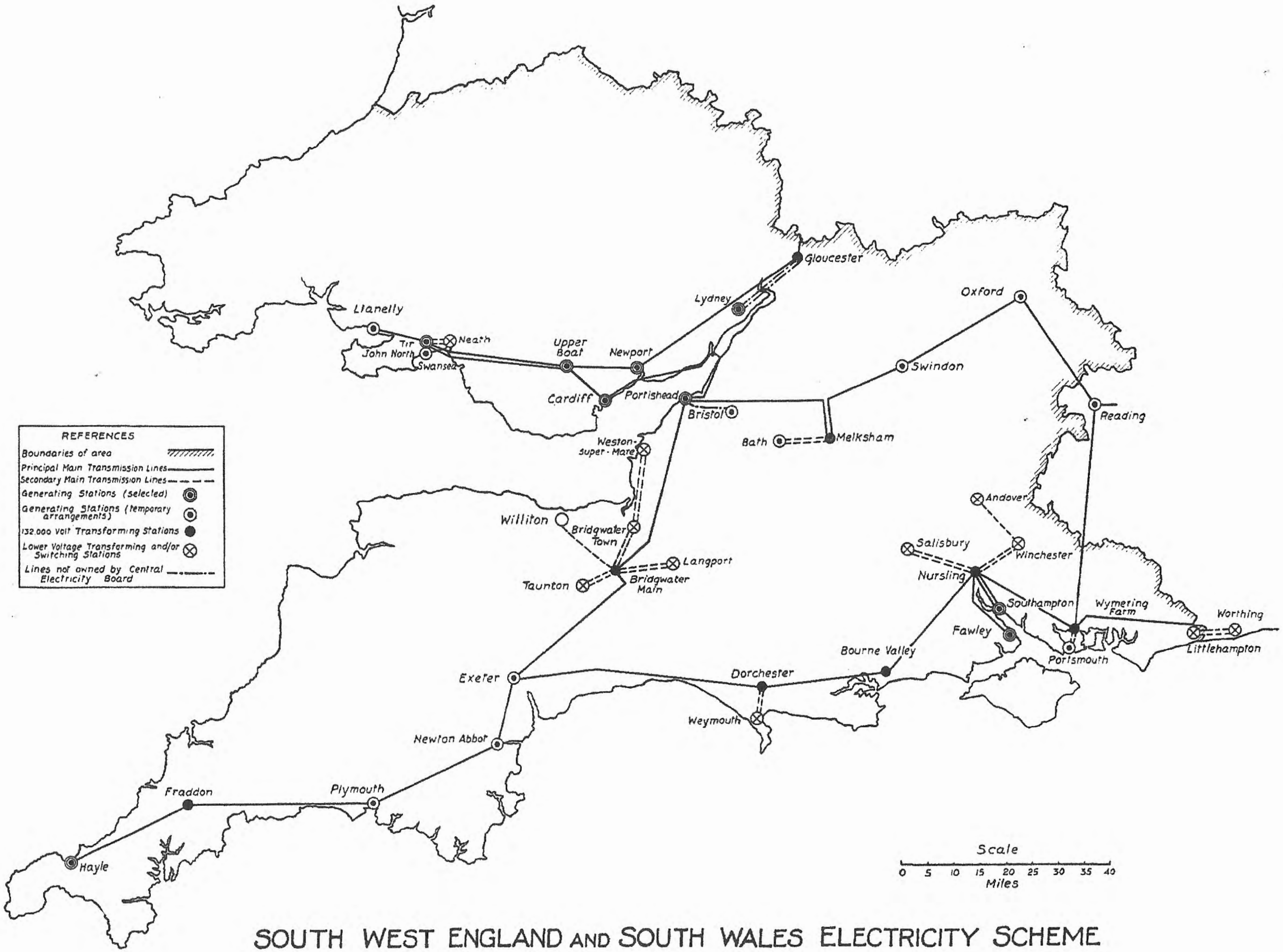
The facilities provided on the N.W. and S.W. "grids" may be briefly summarised as follows:—

(1) Inter-tripping of circuit breakers.
Provided between all stations on the S.W. "grid" and also between certain stations on the N.W. "grid."



NORTH WEST ENGLAND AND NORTH WALES ELECTRICITY SCHEME

FIGURE 1



SOUTH WEST ENGLAND AND SOUTH WALES ELECTRICITY SCHEME

FIGURE 2

(2) The apparatus continually indicates by miniature lamps the condition of each distant circuit breaker, whether " in " or " out."

(3) The apparatus enables bothway telephonic communication to be established between the central indicating station and each distant station.

(4) The apparatus continually indicates the particular tap in use on each distant transformer tap-changing switch.

(5) The apparatus provides remote metering facilities, whereby the summated kW and reactive kVA components on both distant transformers, also the total loads on the generating stations, may be indicated on mechanical meters at the central indicating station at will.

(6) The apparatus enables any one of seven instructions to be transmitted to and acknowledged by each individual generating station by means of a system of engine room telegraphs.

(7) The apparatus provides in certain cases for the signalling operations of two stations to be performed on the " tandem " principle, i.e. over the same pair of wires to the central indicating station.

Of the above, numbers 3, 5 and 6 involve a selective operation but numbers 1, 2 and 4 are entirely automatic and are initiated by the protective gear, a change in position of a circuit breaker or a change in position of a transformer tap-changing switch respectively. The signals are given strictly in the above order, being controlled by the " priority " circuit. Thus the important " inter-tripping " feature ranks higher than all other signals and the circuit arrangements are such that, no matter what other signals may be in course of transmission at the time, the complete operation of " inter-tripping" is accomplished in less than one second. Changes in the positions of circuit breakers are next in priority and, when a change occurs, a complete cycle of operations takes place, whereby not only is the change in the particular breaker indicated but the indications of all the other breakers and the transformer tap-change switches associated with the particular station

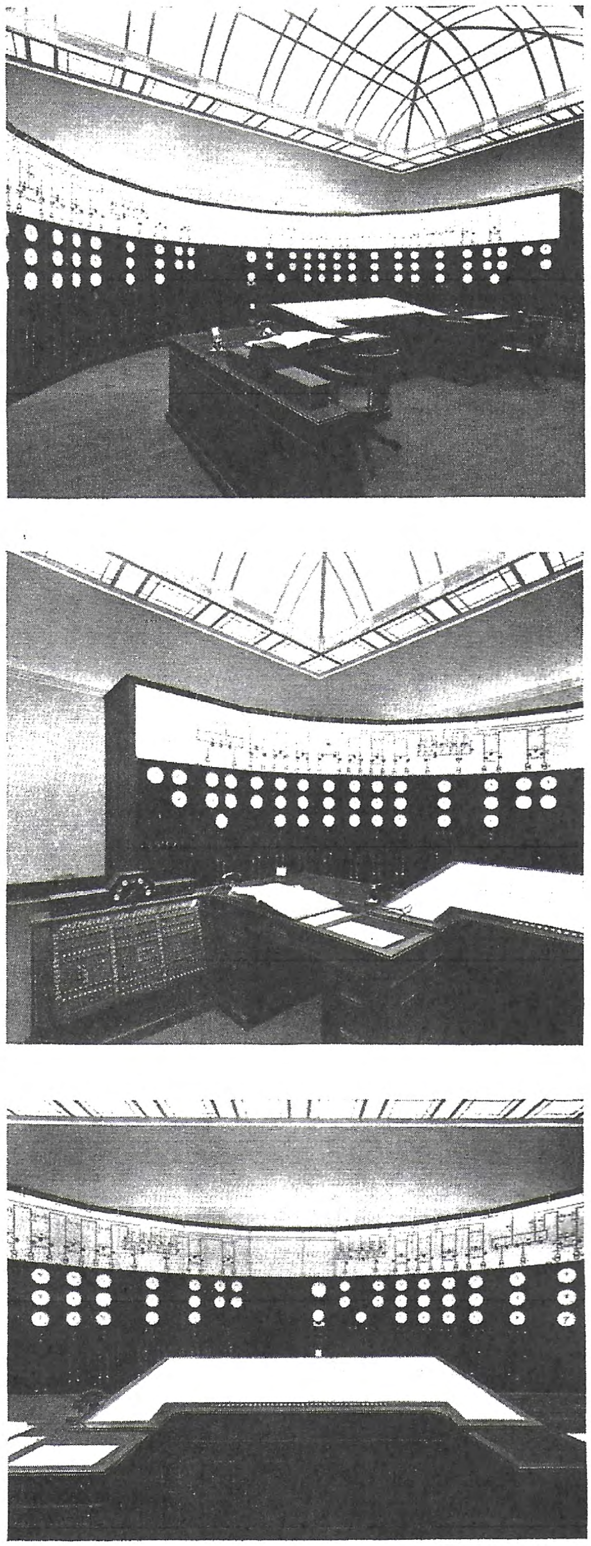


FIGURE 3

are checked and the pointers of the mechanical meters associated with that station are also each rapidly re-set. The duration of the complete cycle of operations in a typical case would be about 30 seconds.

In the case of a change in position of a transformer tap switch occurring, the same cycle of operations is initiated, but in this case, the transmission of the signals would be delayed in the event of a telephone connection being already established. However, under no circumstances are any signals lost.

CENTRAL INDICATING STATION—N.W. " GRID."

Fig. 3 gives views of the central indicating station of the N.W. " grid," which is located in Manchester. The indicating board combines in one unit both the centralised indicating panels and the mimic diagram of the 132 kV. system. The board is curved at a radius of approximately 14 ft. and each panel carries the indicators and meters associated with one station. The top portion of the panel carries the diagram in cream and black, whilst the mechanical meters and illuminated transformer tap switch indicators are mounted on the lower portion. Independent red and green lamp indicators are provided for each circuit breaker.

The control engineers' desk is provided with duplicate control facilities for two engineers, each of whom has his own set of telegraph and telephone controls and an unimpeded view of the miniature diagram. The control engineers, whilst sitting at the desk, have no difficulty in reading the meters and indicators on the main indicating board.

CENTRAL INDICATING STATION—S.W. " GRID."

This is shown in Fig. 4 and is located in Bristol. Unlike the control desks in Glasgow and Manchester, the Bristol desk accommodates the central indicating panels in addition to the miniature diagram and signalling equipment. In this case, the indicators for the circuit breakers consist of a single aperture only, which displays green or red according to the position of the associated breaker. The tap change indicators are of the edgewise electro-mechanical type, instead of the illuminated type, employed on the Central Scotland and N.W. " grids."

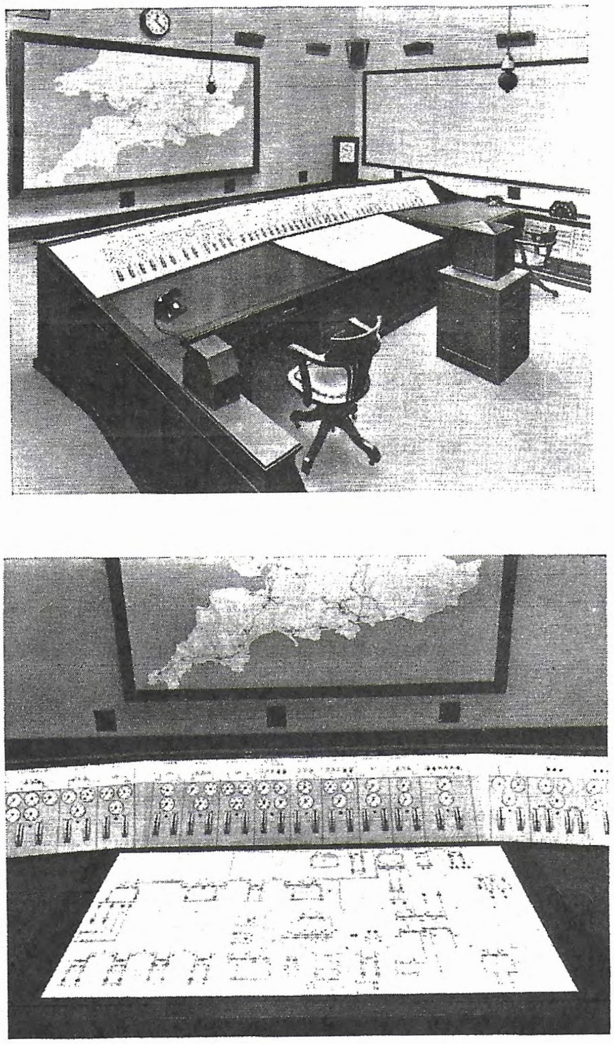
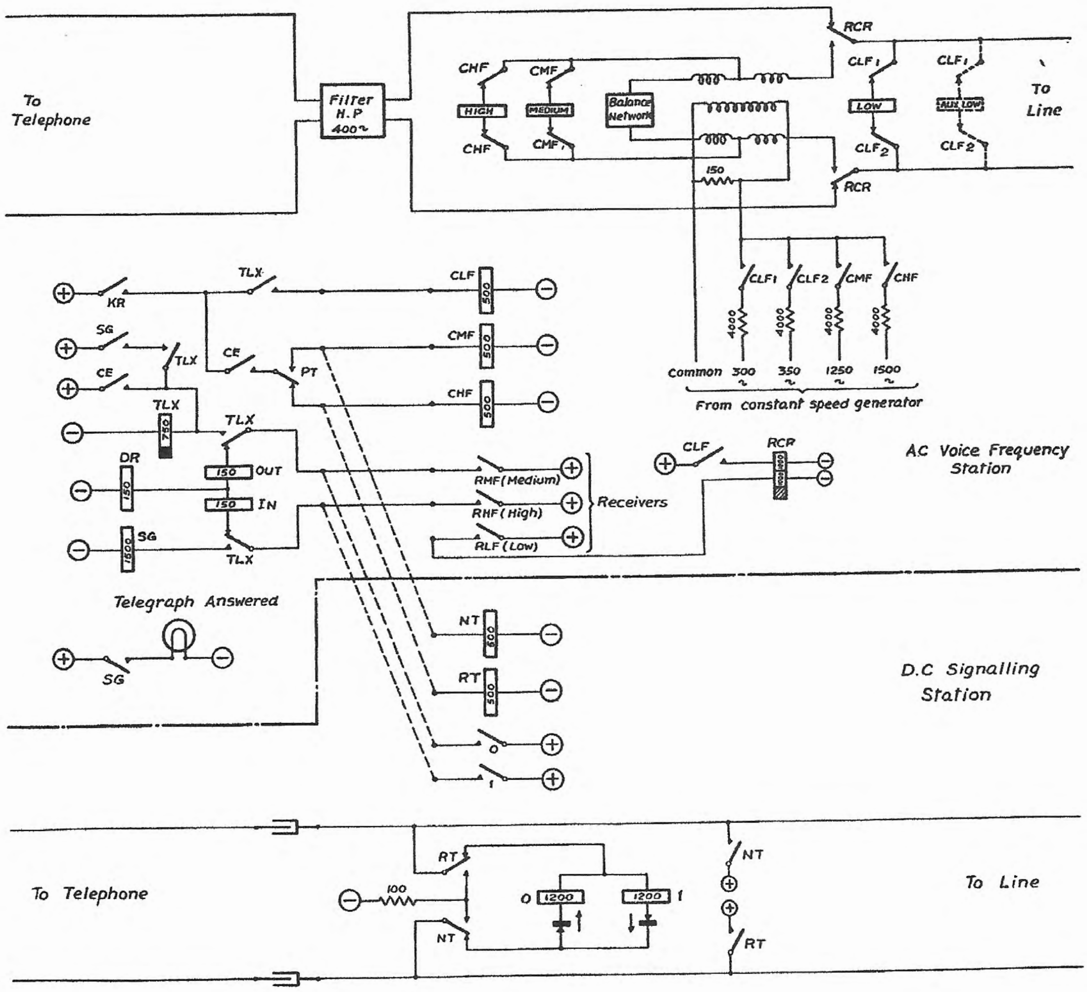


FIGURE 4

N.W. AND S.W. " GRIDS "—LINE CIRCUITS.

Figs. 5 and 6 show the elements of the line circuits employed on the N.W. and S.W. " grids," for both A.C. and D.C. signalling. In the case of A.C. signalling, the line terminates at the sub-station on an isolating transformer, across the secondary of which the low frequency receiver is connected through the normal contacts of relay SLF, the secondary being also extended to the telephone circuit via the normal contacts of relay TCO. The make contacts of the latter are connected to the hybrid transformer and the line balancing network, the latter being designed to simulate the frequency-impedance



Central Indicating Station

FIGURE 5

characteristics of the line in order to ensure high overall operating efficiency. The medium and high frequency receivers are connected across the bridge points of the hybrid transformer, via the normal contacts SMF and SHF respectively, whilst to the hybrid secondary, the low, medium and high frequency oscillators are connected. The latter, though always energised, are normally prevented from delivering power by means of the normal contacts of relays SLF, SMF and SHF. In the general case, when a signal train is initiated at the sub-station, relay SLF is held operated to disconnect the local low frequency receiver and also to apply low frequency to the line. This causes relay RLF of the low frequency receiver at the C.I.S. to be operated, thus in turn operating relay RCR to introduce the high and low frequency receivers to accept incoming impulses.

Simultaneously at the sub-station, relay SE operates and is held operated for one complete train of impulses, thus operating relay TCO to complete the circuit for the transmission of medium and high frequency impulses, as determined by the position of the circuit breakers, tap switches, meters, etc. The latter are connected to successive contacts of uniselector bank DS5 and at each step control the operation

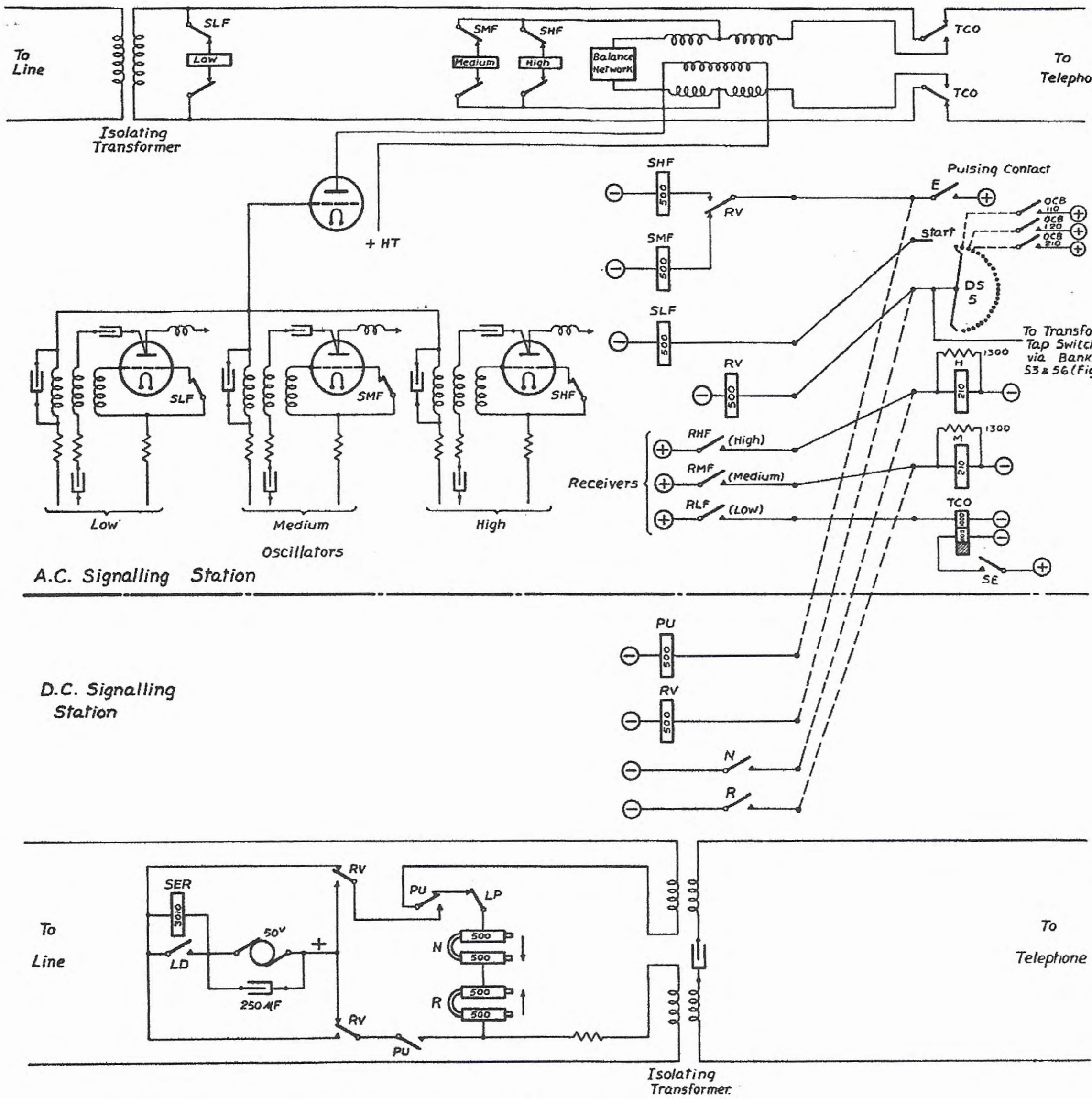


FIGURE 6

of relay RV, which in turn determines whether relay SMF or relay SHF shall be operated via the pulsing contacts E to transmit medium or high frequency to line. At the C.I.S. the incoming impulses actuate their respective receiver relays, and hence, also, relay DR and also either the " Out " or " In " relay.

Whilst the " Out " relay operates with each medium frequency impulse and the " In " relay with each high frequency impulse, relay DR, which controls the stepping action of a uni-selector, is operated at each impulse of either frequency.

Impulse trains are transmitted in a similar manner from the C.I.S., the pulsing contacts CE first operating the slow releasing relay TLX to disconnect the impulse receiving relays DR, " In " and " Out " and relay CLF is operated via operated contacts TLX and KR. The latter relay is operated during the impulse from the selecting keys. The operation of relay CLF operates relay RCR to prepare the circuit for the transmission of the medium and high frequency impulses and also applies low frequency steadily to the line. Relay RLF at the distant station is thus operated and in turn operates relay TCO to introduce the medium and high frequency receivers in readiness to accept their respective incoming impulses.

At the C.I.S. relay PT, which is controlled by the selective apparatus, determines the sequence of operation of relays CMF and CHF via the pulsing contacts CE and the operated contacts KR.

The function of relay SG is associated with the engine room telegraphs. Upon completion of the transmission of a telegraph signal to the distant station, medium frequency is returned over the line to hold relay TLX via its own contacts and operated contacts RMF of the medium frequency receiver. When now the attendant at the distant station replies, high frequency is applied in place of medium frequency, thus operating relay SG to give the acknowledgment signal by lighting the lamp. The control engineer at the C.I.S. can then clear down by restoring the keys.

Referring now to the D.C. signalling system, it will be observed from the diagram (Fig. 6) that the line circuit only is different, being generally more simple than the A.C. line circuit, and that the selective apparatus itself is identical in both cases. At the sub-station the line terminates on an isolating transformer, a group of relays and a 50 volts dynamo, which collectively form the line isolating equipment. Relays N and R are of the non-locking polarised type, and are so connected that they respond to current in different directions. The contacts PU are for pulsing, whilst relay RV, controlled by the positions of the circuit breakers, tap switches, meters, etc., determines the polarity of the impulses transmitted to line.

Relay SER is the line-testing relay and it ensures that the C.I.S. equipment is ready to receive signals before starting the impulse train. Relay LD short-circuits relay SER after the first impulse in order to enable a higher impulsing speed to be attained.

At the C.I.S., relays O and I are connected in parallel across the line, each in series with a metal rectifier. As these relays are polarised, the function of the metal rectifiers is to prevent one relay from shunting the other, which would lower the efficiency of the line circuit. Relays NT and RT serve to apply currents to line in one direction or the other as determined by the selective apparatus, via the operated contacts KR, pulsing contacts CE and reversing contacts PT.

Operation of the Transmitting Circuits at the Sub-Station for Circuit Breaker, Tap Change and Metering Indications.

In comparison with the earlier Central Scotland signalling system, an important simplification has been effected in the case of the N.W. and S.W. "grid" apparatus, in that, at the sub-stations, pairs of relays are not associated with each individual circuit breaker and transformer tapping, but, instead, uniselectors are employed as shown in Fig. 7. The diagram shows the arrangement for a station having three circuit breakers and two transformer tap-changing switches.

Considering first the circuit breakers, it will be seen that, normally, the wipers CBA will be standing so that the circuit from battery through the two windings of relay CS and the driving magnet and interrupter contacts of CBA, is disconnected. When now a change in circuit breaker position occurs, this circuit is completed through the particular bank and wiper and relay CS operates but, at first, the current is insufficient to fully energise the driving magnet. The operation of relay CS in turn operates relay RSR, which locks up until transmission of the train of impulses commences. The operation of relay RSR short-circuits the 1,000 ohms winding of relay CS, thus fully energising the driving magnet CBA, which therefore hunts to step the wipers until the circuit is again disconnected through the new arrangement of the circuit breaker auxiliary contacts. Shortly after this operation has been completed, relay CS releases and completes a circuit via the temporarily operated RSR contacts to operate relay SE, which locks up for one complete train of impulses.

Considering now the transformer tap-changing arrangements at the sub-stations, it will be seen that a uniselector is associated with each set of transformer tap-changing gear and that the driving magnets are commoned, with the circuit breaker uniselector, to relay CS. Normally, each of the relays TA and TB will be held energised via bank TMA3 and TMB3 and the operated auxiliary contact of the particular tappings in use, thus maintaining opened the

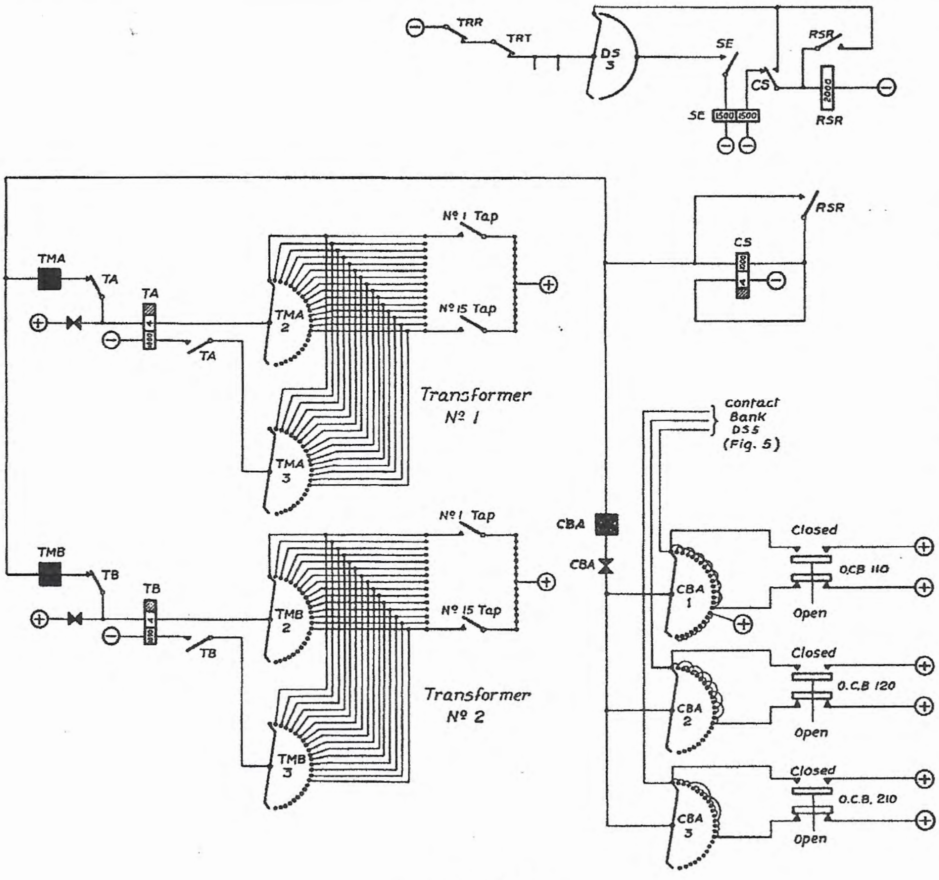


FIGURE 7

circuit via relay CS and the driving magnets. When now any change in position occurs, the corresponding relay TA or TB releases, thus operating relays CS and RSR and causing the particular uniselector to hunt for the new position. When this is found, the 4 ohms winding of the corresponding relay is energised when the interrupter springs open and the relay remains locked on the next contact via its 1,000 ohms winding, the corresponding bank No. 3 and the newly operated auxiliary contacts. This opens the circuit of relay CS, which releases shortly afterwards and then initiates one complete train of impulses.

The manner in which the impulses are transmitted to line will be gathered from Fig. 8. As mentioned above, whenever a change in position occurs, relays CS, RSR, and SE operate in sequence. At first, relay RSR is held via the home contact of bank DS3 and the normal contacts TRT and TRR, but, when CS releases, relay SE is operated to complete a circuit for relay E via the interrupter contacts S and DS. Relay E therefore operates and fully energises driving magnet DS via banks DS2 and wiper and operated E contacts. The interrupter contacts DS then open to release relay E, thus disconnecting the driving magnet and stepping the wipers DS on to the second contacts. A locking circuit is now completed via bank DS3 for relay SE, which remains held for one complete sweep of the wipers. When therefore the interrupter contacts DS again close, relay E re-operates to again fully energise the driving magnet DS, and this cycle of operations continues and steps the wipers steadily round the banks at about ten steps per second.

Considering now bank DS5 it will be seen that the first set of contacts are connected to the auxiliary contacts of the various circuit breakers, these contacts being closed when the breakers are "in." Consequently relay RV will be operated for each breaker that is "in," but will remain normal for each breaker that is "out." Thus, at each step of the uniselector DS, relay SHF operates via pulsing contacts E to transmit an impulse of high frequency for each breaker that is "in" and a medium frequency impulse for each breaker that is "out."

The transformer tap signals follow the circuit breaker signals and these are transmitted by retaining uniselector DS on the 18th contact, and meanwhile stepping uniselector S for one complete revolution of its wipers. Under this condition the pulsing circuit for uniselector S is via wiper DS2 on the 18th contact and pulsing

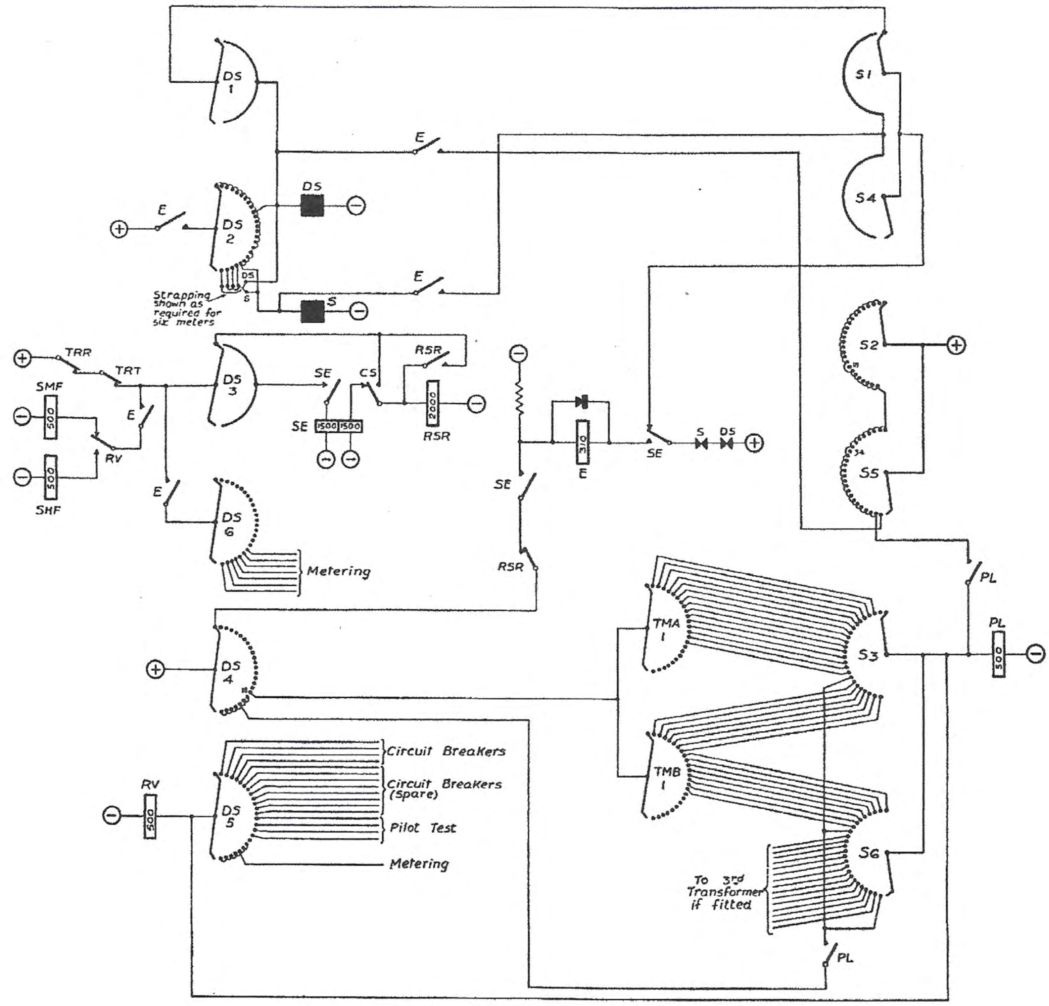


FIGURE 8

contacts E. The control of relay RV is via wiper DS4 on the 18th contact, the transformer tap marking uniselector banks TMA and TMB and the stepping wipers S3 and S6. As the latter step round, relay RV remains normal on the earlier contacts until the contact on which wiper TMA 1 is standing is reached. Relays RV and PL then operate and lock up via operated PL contacts, the common wiring on banks S5 and S2 and wiper S2 to positive. Consequently, relay SMF is operated at each step up to the marked contact to transmit a medium frequency impulse, but relay SHF operates at each remaining step in the group to transmit a high frequency impulse. Relays RV and PL are released via the unstrapped 18th contact and the same cycle of operations is then repeated for the second transformer tap via uniselector bank TMB, relays RV and PL releasing at 34th contact.

A third transformer could be similarly dealt with.

Finally, uniselector DS is stepped on to the next contact via the 50th contact and wiper S5. This prepares the first metering circuit, a detailed description of which will be deferred until the principles of contact metering have been outlined. For the present it will suffice to note that uniselector S is stepped one complete revolution, i.e. 50 steps for each meter, uniselector DS being stepped to the next meter at the 50th step of uniselector S. It should be noted that, when metering, relay RV

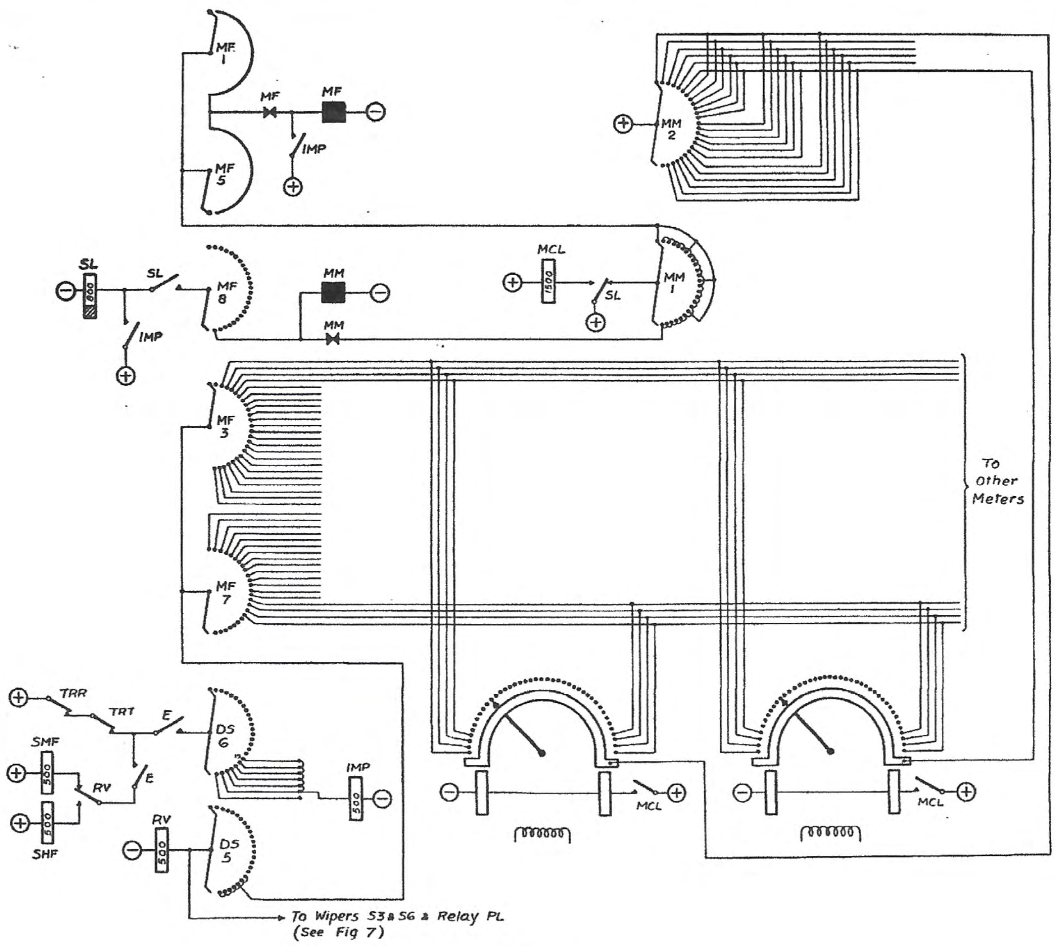


FIGURE 9

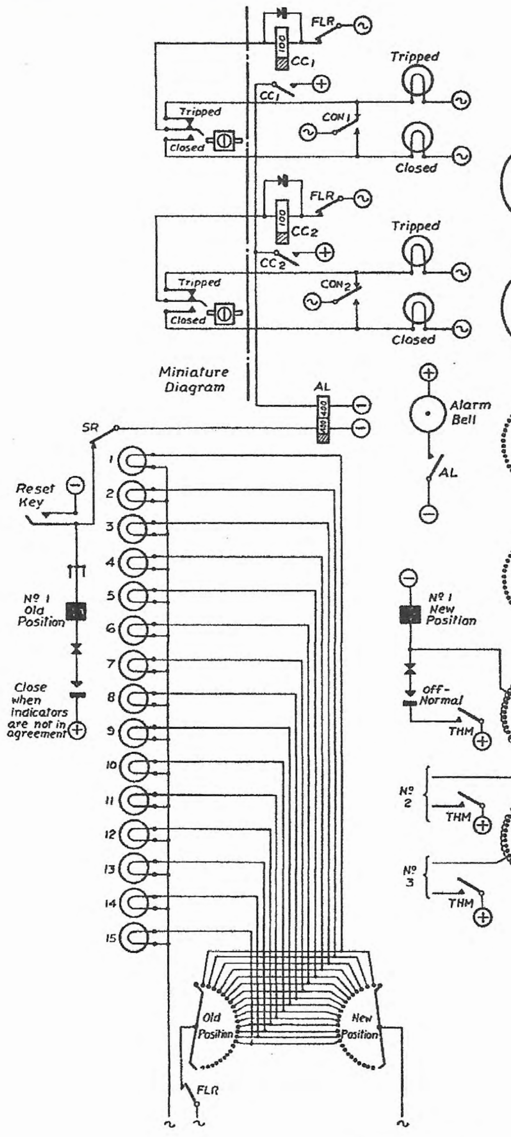
remains locked for the remainder of the fifty impulses after the marking contact is reached, this being accomplished via the commoned contacts S2 and S5 or the commoned 18th, 34th and 50th contacts of banks S3 and S6, operated PL contacts and the commoned contacts of DS4, on which wiper DS4 is standing during the metering operations.

Referring to the strappings of the metering contacts on bank DS2, these are shown for a group of six meters. If fewer meters are encountered, then the later contacts are strapped to DS instead of S.

Fig. 9 is a schematic diagram showing the elements of the metering transmission circuit as used in the N.W. and S.W. "grids," the particular arrangement shown being for a group of six meters.

It will be seen from the diagram that a pulsing circuit for relay IMP is completed via the 19th contact and wiper DS6, pulsing contacts E and normal contacts TRT and TRR. Relay IMP now commences to pulse and continues to do so until all the readings of all the meters have been transmitted in succession. At the first operation of relay IMP, slow release relay SL is operated and remains steadily operated throughout the metering operations. Relay SL in turn operates relay MCL, which clamps the pointers of all the six meters to "mark" their respective commonings on bank MF3 and MF7.

Uniselector MF takes one step for each pulsation of relay IMP, relay SMF being also operated at each step, until the marked contact is reached, to transmit a medium frequency impulse. When the marked contact is reached, a circuit is completed for relay RV via wiper and bank DS5, wiper and bank MF3 or MF7,



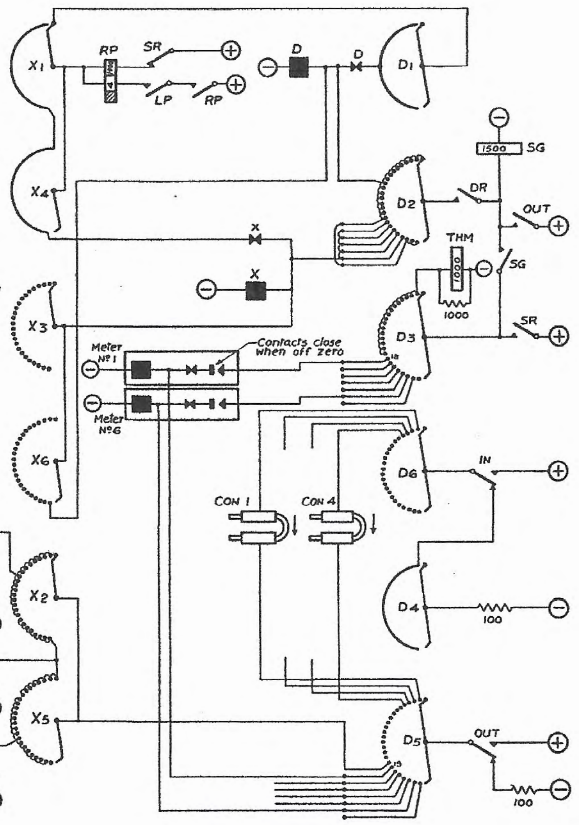


FIGURE 10

the clamped marking contacts on the meter being read and the particular contact and wiper MM2 to positive. Relay RV then remains locked up for the remaining impulses of the metering cycle via operated contacts of relay PL, which relay, as previously mentioned, releases together with relay RV at the conclusion of the transmission of each meter reading.

At the 50th step of uniselector MF an impulse is given to uniselector magnet MM via bank MF8, operated contacts SL and pulsing contact IMP, thus introducing meter No. 2, the reading of which now commences to be transmitted. The remaining meters are similarly introduced and their readings transmitted.

Uniselector S (see Fig. 8) steps in unison with uniselector MF, so that uniselector DS is stepped via the 50th contact of bank S5 and thus steps at the same time as uniselector MM.

It will be seen that if the metering operation is interrupted for any reason, as for instance the opening of the contacts TRT or TRR due to the intertripping feature being suddenly called upon to function, the uniselectors MF and MM are immediately "homed" on the release of relay SL.

OPERATION OF THE RECEIVING CIRCUITS AT THE C.I.S. FOR CIRCUIT-BREAKER, TAP CHANGE AND METERING INDICATIONS.

Before proceeding to consider the operation of the receiving circuits, attention is drawn to the following summary of the nature and sequence of the impulses transmitted from the sub-station in one complete cycle of circuit breaker, tap switch and metering signals.

(1) *Circuit Breakers.* An impulse of high frequency is transmitted for each breaker that is "in" and an impulse of medium frequency for each breaker that is "out."

(2) *Transformer tap switches.* An impulse of medium frequency is transmitted for each of the taps preceding the one in use, an impulse of high frequency being transmitted for each of the remaining taps. A total of fifty impulses is transmitted for three transformer tap switches.

(3) *Metering.* An impulse train of fifty impulses is transmitted for each meter being read. A medium frequency impulse is transmitted for each contact preceding the one "marked" and a high frequency impulse for each of the remaining contacts.

(a) Circuit Breaker Indications.

Considering now the diagram Fig. 10, the "out" contacts operate at each medium frequency impulse and the "in" contacts operate at each high frequency impulse, whilst the contacts DR operate at impulses of both medium and high frequencies. Consequently during the reception of impulses the contacts DR are continually pulsing and these contacts close the circuit for slow release relay SR, which remains operated throughout the pulsing.

The circuit breaker, tap switch and metering train of impulses is always preceded by a medium frequency impulse; consequently this operates the "out" relay to energise relay SG, which locks up for the train of impulses via operated contacts SR. This first impulse, therefore, energises the driving magnet D via pulsing contacts DR, and at the conclusion of the impulse, DR releasing, causes the uniselector D to step to the second contacts, to which the magnetic locking relay CON1 is connected between banks D6 and D5. The next impulse is a breaker impulse, the "in" contacts operating if breaker No. 1 is "in" and the "out" contacts operating if No. 1 is "out." The various CON relays are consequently set in succession as the uniselector D is stepped round the bank, in accordance with the particular impulses received.

Referring to the left-hand upper corner of Fig. 10, it will be seen that unless the various contacts in the miniature diagram are set in accordance with the signal lamps, the relays CC1, CC2, etc., operate to energise relay AL to sound the alarm bell. The contacts FLR operate intermittently, by means not shown in the diagram, thus causing a "flickering" effect on the lamp associated with the breaker that has changed position. It will be observed that, when a change occurs, the particular CON relay contacts change over, thus removing a short circuit via the operated contacts of the indicator on the miniature diagram, winding of one of the CC relays and the pulsing FLR contacts. Thus whilst the new position is indicated by the steady glowing of the corresponding lamp, the lamp associated with the old position flickers and the alarm bell sounds until the corresponding indicator on the miniature diagram is actuated to the changed position. The flickering lamp is then disconnected and the alarm ceases.

(b) Tap Switch Indications.

It will be seen from the diagram that, immediately uniselector D steps off the home position, relay THM is operated via wiper D3 and operated contacts SR to positive. The operation of relay THM "homes" the "new position" uniselector associated with each of the tap change switches, the off-normal contacts opening when the home position is reached in readiness to be re-stepped when the tap change pulses are received.

When uniselector D reaches the 18th contacts, the driving magnet X is pulsed instead of D and, consequently, commences to step its wipers. It will be remembered that a medium frequency impulse is transmitted from the sub-station for each contact preceding the one in use, the remaining impulses in the train being of high frequency. Each medium frequency impulse actuates the "out" relay, thus stepping the driving magnet of the No. 1 "new position" uniselector, which, however, is not stepped by the complementary number of high frequency impulses, which actuate the "in" relay. At the end of the No. 1 tap switch impulse train, the high frequency impulses change due to the releasing of relay RV at the sub-station and the No. 2 tap switch impulse train comes in, commencing with medium frequency impulses as before. The No. 3 tap switch signals are similarly received, and at the 50th step of uniselector X, an impulse is given to uniselector D to complete the metering circuit, the impulse trains for which follow in the manner to be described later.

If since the last cycle of circuit breaker, tap switch and metering impulses there has been no change in the position of any of the tap switches, the lamp signals for the latter, whilst they " flicker " during the receipt of impulses, glow steadily to indicate the particular taps in use upon completion of the full impulse train. If, however, a change has taken place, then, when relay SR finally releases, one of the " new position " uniselectors will be standing on a different contact to its corresponding " old position " uniselector. Under this condition of difference in alignment of the two sets of wipers, an auxiliary set of contacts close and complete a circuit via the " old position " driving magnet, restored contacts SR and one winding of relay AL, which operates to give the alarm. At the same time, the lamp corresponding to the position last in use is caused to flicker via the " old position " wiper and flickering contacts FLR. The control engineer, by actuating the re-set key, causes the " old position " uniselector to hunt until the old and new position uniselectors are in alignment, thus leaving a single lamp glowing steadily to indicate the particular tap in use.

(c) *Meter Readings.*

As at the sub-station, uniselector D is shown strapped for six meters. During the time that the tap switch train of impulses is coming in, meter No. 1 is being " homed " to zero, via the strapping of the 18th contacts of bank D3 and operated contacts SR to positive. Upon completion of the tap switch train of impulses, uniselector D steps, thus bringing its wipers on to the 19th contact.

Meter No. 1 is then stepped by " out " impulses until the marked contact is reached, and thus takes up a position corresponding to the initiating instrument. Whilst meter No. 1 is being set, meter No. 2 is " homed " via bank D3. At the end of 50 impulses associated with meter No. 1, uniselector D takes one step to home meter No. 3 and also provides an impulsing circuit for meter No. 2.

In this manner all the meters are set in succession to correspond with the new readings.

It will be appreciated that the accuracy of the displayed signals and metering readings at the C.I.S. depend upon the transmitting uniselectors at the sub-station and the C.I.S. remaining in step. It is therefore of the utmost importance to prove that the essential synchronism has been maintained throughout the complete cycle of impulses. This is definitely ensured by relay RP, which, as previously described in connection with the Scottish " grid " circuits, remains normal if synchronism has been maintained but otherwise operates and causes a repetition of the complete impulse train.

The duration from start to finish of a train of signalling impulses for a normal sub-station having three meters is approximately 22 seconds, being increased to about 37 seconds if six meters are fitted. The control engineer can at any time initiate the complete impulse train by simply actuating the " check " key. This facility, besides providing for the occasional functional testing of the apparatus, also enables meter readings to be obtained periodically for logging purposes.

INTER-TRIPPING OF CIRCUIT BREAKERS.

The function of " inter-tripping " is to ensure that, in the event of any circuit breaker being tripped due to a line fault, the companion breaker at the other end of the line is automatically tripped with the least possible delay. By means of A.T.M. Strowger equipment it has been possible to reduce the time taken for this operation to something below the $1\frac{1}{2}$ seconds specified, in some instances, in fact, to a figure as low as 0·8 of a second.

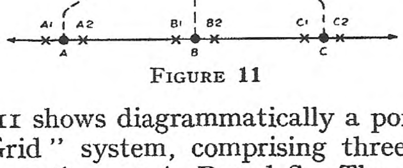


FIGURE 11

Fig. 11 shows diagrammatically a portion of the " Grid " system, comprising three transforming stations at A, B and C. The stations are connected together by single lines AB and BC, and form part of a ring system. It will be seen that each line is protected by a circuit breaker at each end.

The dotted lines represent the single pairs of signalling wires that connect each distant station to the central indicating station.

It will be clear that, in the event, say, of circuit breaker B1 in station B tripping on a line fault, circuit breaker A2 in station A must be brought out. Similarly, if circuit breaker B2 comes "out" in station B, then circuit breaker C1 in station C must be opened. Normally the tripping of the appropriate switches would be performed by the protective gear, but, in special cases, with which it is outside the scope of this article to deal, the clearance time may be considerably reduced by use of the inter-tripping facility.

The inter-tripping function ranks highest in order of priority and means are therefore provided so that, no matter what signals may be taking place when a circuit breaker " trips " on fault, the inter-tripping function is immediately able to be effective. Briefly, this is accomplished by first applying the low, medium and high frequencies simultaneously to line. This composite impulse is then followed by three receiver-proving impulses or " codes " of the three combinations of two frequencies only. Finally, all three frequencies are again simultaneously transmitted to trip the breaker.

Provision is made for six different codes as follows :—

	Order of transmission.		
Code	1st	2nd	3rd
No. 1	—	L	L
	M	—	M
	H	H	—
No. 2	—	L	L
	M	M	—
	H	—	H
No. 3	L	—	L
	—	M	M
	H	H	—
No. 4	L	L	—
	M	—	M
	—	H	H
No. 5	L	—	L
	M	M	—
	—	H	H
No. 6	L	L	—
	—	M	M
	H	—	H

These six combinations provide adequately for the inter-tripping requirements on the N.W. and S.W. " grids."

In the case of the N.W. " grid," A.T.M. Strowger inter-tripping apparatus is only included on the Ribble-Lancaster-Kendal-Carlisle line.

On the other hand, in the S.W. " grid," A.T.M. Strowger inter-tripping is provided over the whole area. Approximately half the stations are operated over a single pair of wires, the remainder working on the " tandem " principle, two stations being served over one pair of wires. Actually, inter-tripping between stations connected to the same pair of wires is extremely simple, since the signals have not to be repeated from the C.I.S., at which it is only necessary to " guard " the line during the brief period during which the inter-tripping operation is accomplished.

" TANDEM " WORKING.

In view of the relatively large proportion of " tandem " working employed on the S.W. " grid," it will be of interest to examine the circuit arrangements employed to ensure that the signals between the two stations on the same pair of wires do not mutually interfere with one another. As previously mentioned, the line frequency assigned to one of the tandem stations is 300 cycles and 350 cycles is assigned to the other. In all other respects the equipment at the two stations is identically the same.

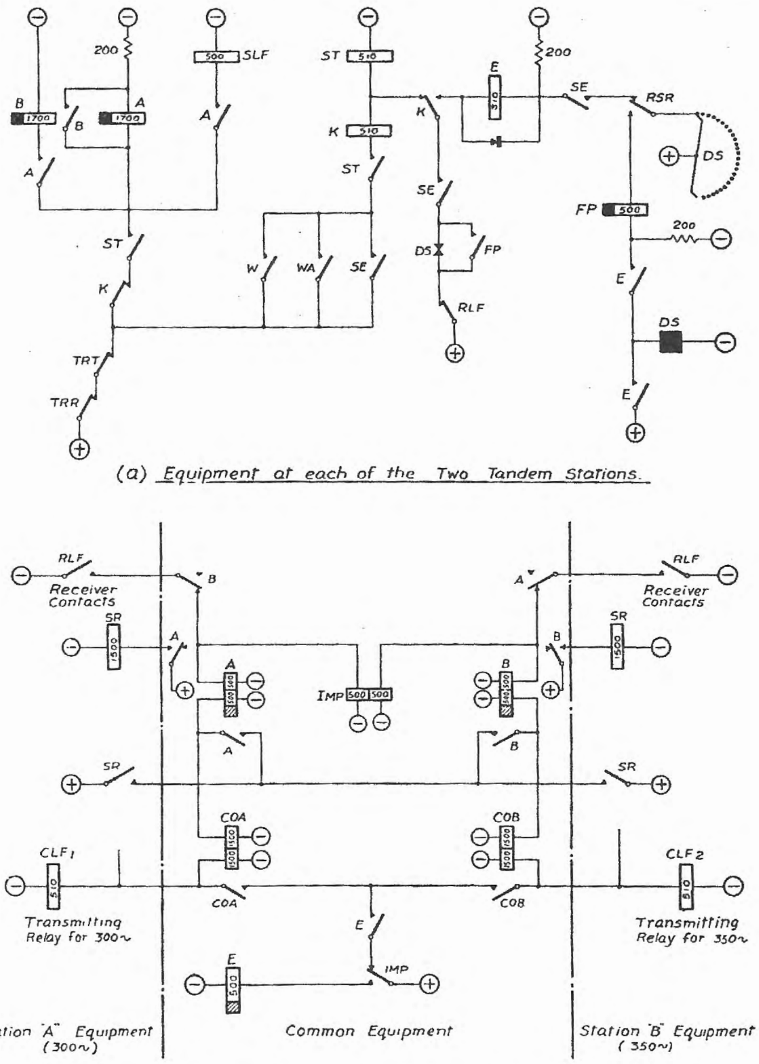
It will be appreciated that if a change occurs on one station during the period that the other station is either receiving or transmitting impulses, then the existing train must not be interfered with if the new signals are of lower priority and transmission of the signals must be delayed until completion of the existing impulse train.

These requirements are adequately met by means of the priority circuit in conjunction with the circuit shown in Fig. 12. This circuit depends for its operation on a revertive impulse from the C.I.S., this impulse only being transmitted to enable the signal train to commence if the line is otherwise free. Until the revertive impulse is transmitted, low frequency " challenging " impulses are applied to the line by the particular station at intervals of about one second. As these "challenging" impulses are of different frequency to the low frequency of the existing train of impulses, no interference takes place.

The circuit operation is as follows:—

Referring to Fig. 12 (*a*), relay RSR (contacts only shown) operates and locks wherever a change occurs and in turn operates relay FP and also relay SE (contacts only shown). Relay ST then operates via normal contacts K, operated SE contacts, normal DS interrupter contacts and normal contact RLF. The latter are the contacts of the low frequency receiver, which it will be remembered is removed from the line during the period that low frequency is applied to the line at the particular station.

The operation of relay ST completes the circuit for relay A, via operated contacts ST and normal contacts K, TRT and TRR to positive. Relay A operates SLF to apply low frequency to line, also simultaneously disconnecting the local low frequency receiver. Relay A also operates relay B, which short-circuits relay A. Both relay A and relay B are of the slow-operating, slow-releasing type, and are adjusted to interact at about five operations of each per four seconds.



(*a*) Equipment at each of the Two Tandem Stations.

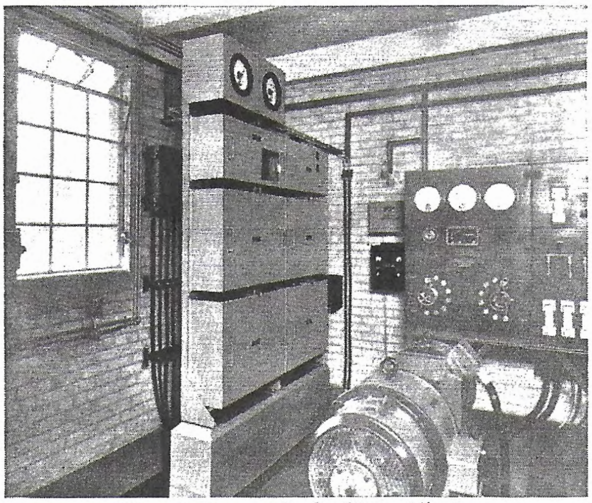
(*b*) Equipment at the C.I.S for Two-Station Tandem Working

FIGURE 12

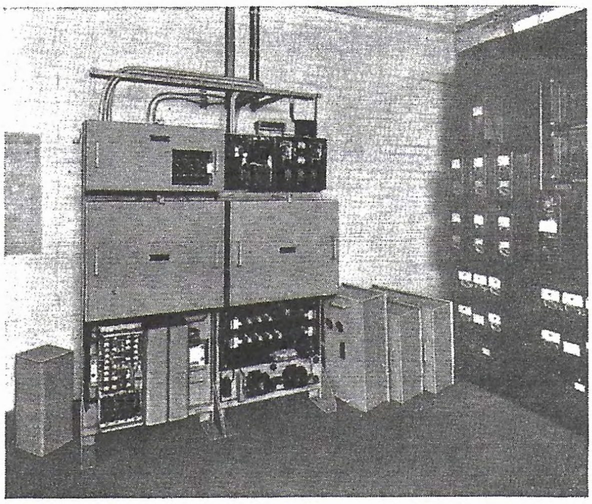
At the first operation and releasing of relay A an impulse of low frequency is transmitted for a period of about half-a-second and thus actuates the corresponding RLF relay at the C.I.S.—see Fig. 12 (*b*). Assuming that the impulse is of 300 cycles, the relay A operates via normal B contacts, disconnecting the RLF contacts of the 350 cycles receiver. Relay IMP also operates over the same circuit as relay A, and thus operates slow release relay E. Relay A operates relay COA, which prepares a circuit for the low frequency transmitting relay CLF1, via operated contacts COA and operated E contacts. Relay IMP releases immediately the pulse on the line ceases and thus completes the circuit for relay CLF1, which then operates to transmit a low frequency impulse from the C.I.S. This impulse operates relay RLF at the sub-station—see Fig. 12 (*a*)—and thus removes a short-circuit from relay K, which operates in series with relay ST, via operated SE contacts and normal contacts TRT and TRR.

The operation of relay K thus disconnects the circuit of the two relays A and B and

Clarence Dock, Liverpool. A.C. Signalling.

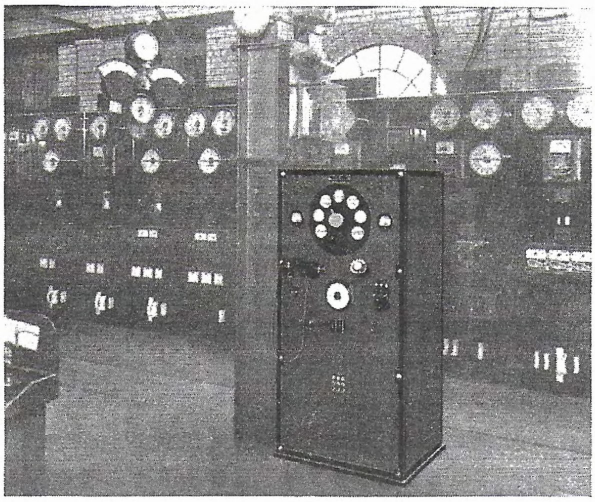


Warrington. D.C. Signalling.

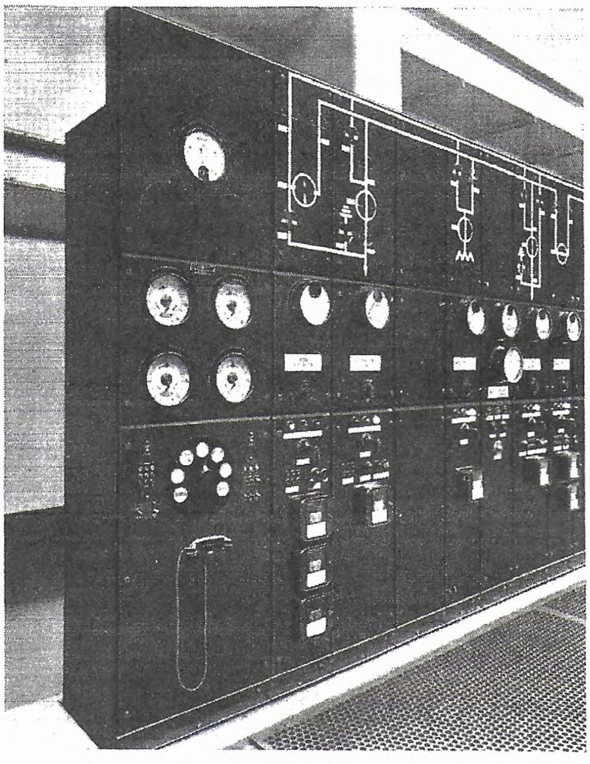


Barton, Manchester. D.C. Signalling.

FIGURE 13



Wallasey, Cheshire.



Barton, Manchester.

FIGURE 14

introduces relay E, which then operates and short circuits relay FP. On the release of relay FP the impulse train commences. Relay RSR releases at the first step of uniselector DS and thus maintains open the circuit for relay FP. Relays K and SE remain operated for the complete impulse train.

It will be observed that, in the event of the second station coming on the line to transmit impulses, the " challenging " impulse continues to be transmitted until the revertive impulse from the C.I.S. is received. This can only be sent when relay A is released at the end of the existing impulse train.

At the sub-station it will be observed that the positive battery to many of the important circuits is fed via relays TRT and TRR to ensure that the inter-tripping signals will not be interfered with by these circuits. Relays TRT and TRR are used in inter-tripping circuit.

MOUNTING OF THE SIGNALLING APPARATUS.

For the sub-stations, the Strowger signalling apparatus is assembled in self-contained groups of relays and uniselectors, which " jack-in " to the permanent wiring of the mounting racks. For the most part, the apparatus is fitted with both inner and outer covers and these are normally kept locked.

Fig. 13 shows typical installations in various sub-station plant houses.

Alternative methods of mounting the apparatus in the generating stations are shown in Fig 14. At Wallasey, for example, the hand-operated total load indicator, engine room telegraph and telephone apparatus is shown accommodated as a self-contained unit in front of the main switchboard. On the other hand at Barton, this apparatus is shown mounted on the end panel of the Central Electricity Board's main switchboard.

For permission to publish the above, also for certain of the photographs, we are indebted to the Central Electricity Board.