AUTOMATIC CENTRALISED INDICATION OF METERS AND CIRCUIT BREAKERS ON POWER NETWORKS

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SYNOPSIS.

Reference is first made to the increasing tendency at the present time to concentrate at some central point the control of large power Networks—The Scottish " Grid " Area and the particular form of centralised control employed thereon is outlined—Then follows detailed descriptions of the applications of " Strowger " Relays and Rotary Switches employed to effect the required control—Line Circuit for Voice Frequency Signals—Circuit Breaker Indications by Impulses of Voice Frequency Currents—Meter Readings by Impulses of Voice Frequency Currents—Midworth Repeater Apparatus—" Strowger " Mechanical Meter.

The tendency at the present time on large power networks is to concentrate, at some central point, the control of the various generating stations and sub-stations. The particular form of control employed depends to some extent upon the network concerned and may include the starting, stopping, and regulation of machines, together with a rapid signalling and indicating system, which keeps the controlling official informed of the conditions of the plant at each distant point.

A typical example is the Central Scotland Electricity Scheme, colloquially known as

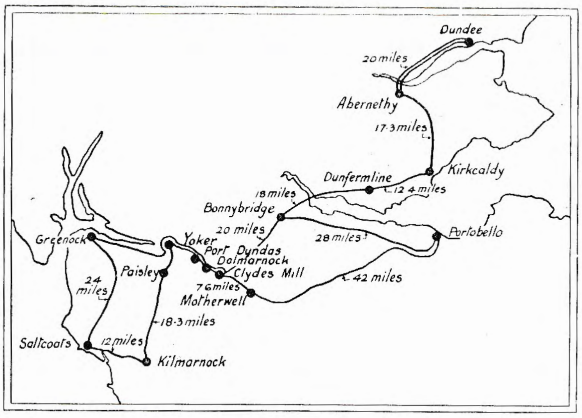

FIGURE 1

the Scottish " Grid," which includes fifteen main power distribution points operating at 132 kV, 3 phase, 50 cycles. The geographical disposition of the fifteen main centres is shown in the map—Fig. 1. Complete control of the entire " Grid " is vested in the Central ndicating Station in Glasgow, where indications of the circuit breakers and transformer tap changing switches at each of the outlying stations are continually displayed. The central indfcating board is shown in Fig. 2. Telephonic communication may be established between each power distributing point and the Central Indicating Station. A system of engine-room telegraphs is also provided by means of which seven specific instructions may be given by the Central Indicating Station to any generating station, acceptance of these instructions being indicated on the initiating telegraph head. Furthermore, by means of remotely controlled Strowger selective apparatus, in conjunction with Midworth repeaters, readings of kW and kVA on any of the feeders, also total loads, at each of the stations, may be indicated on mechanical meters at the Central Indicating Station.

The various signals, indications and communications are effected over two-wire telephone cable lines, rented for the purpose from the British Post Office, one pair of wires being employed between the Central Indicating Station and each of the fifteen distributing points. On account of the small gauge of conductor employed, the weight being mainly 40 lbs. per mile, the inherent attenuation equivalents of the signal lines to the more distant stations are too high for satisfactory speech transmission. Consequently, in five cases, the signal lines pass through thermionic repeater stations and in these cases signalling impulses of voice frequency currents are employed. The lines to the remaining ten stations do not pass through repeaters and consequently the signals over these are transmitted by means of direct current impulses.

The employment of commercial telephone lines in place of the more usual privately-owned pilot wires affects the design of the signalling apparatus to a considerable extent. In the case of pilot wires, which, as a rule, are in the form of small cables of minimum lengths, the question of slight overhearing between the pilot wires and other wires in the same cable is not of great importance. On the other hand, the prevention of overhearing on commercial telephone cables is of vital importance, and, to eliminate the possibility of trouble occurring from this cause, the power of the signalling currents is limited to 0·001 watt for the voice frequency stations and to 0·5 watt for the D.C. stations. The corresponding values that might have been employed over privately

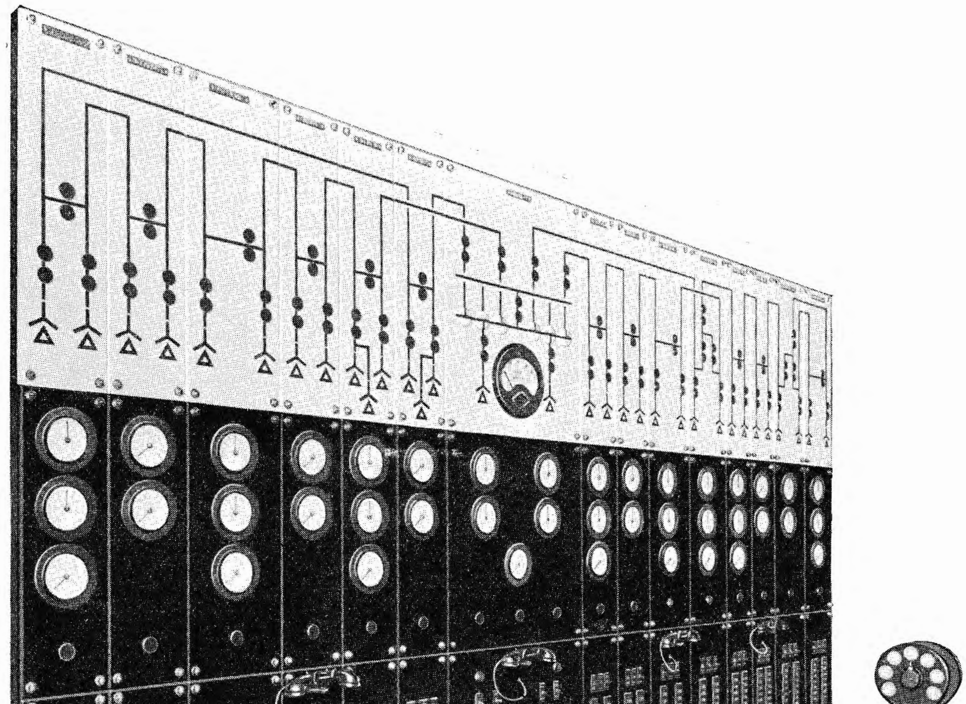

FIGURE 2

Central Indicating Board for the Scottish "Grid" Area owned pilot wires would be about 0·01 watt and 1·5 watts respectively.

The various signal facilities are provided in the following order of priority :—

(1) Changes in position of circuit breakers.

(2) Changes in position of transformer tap-changing switches.

(3) Telephone communications.

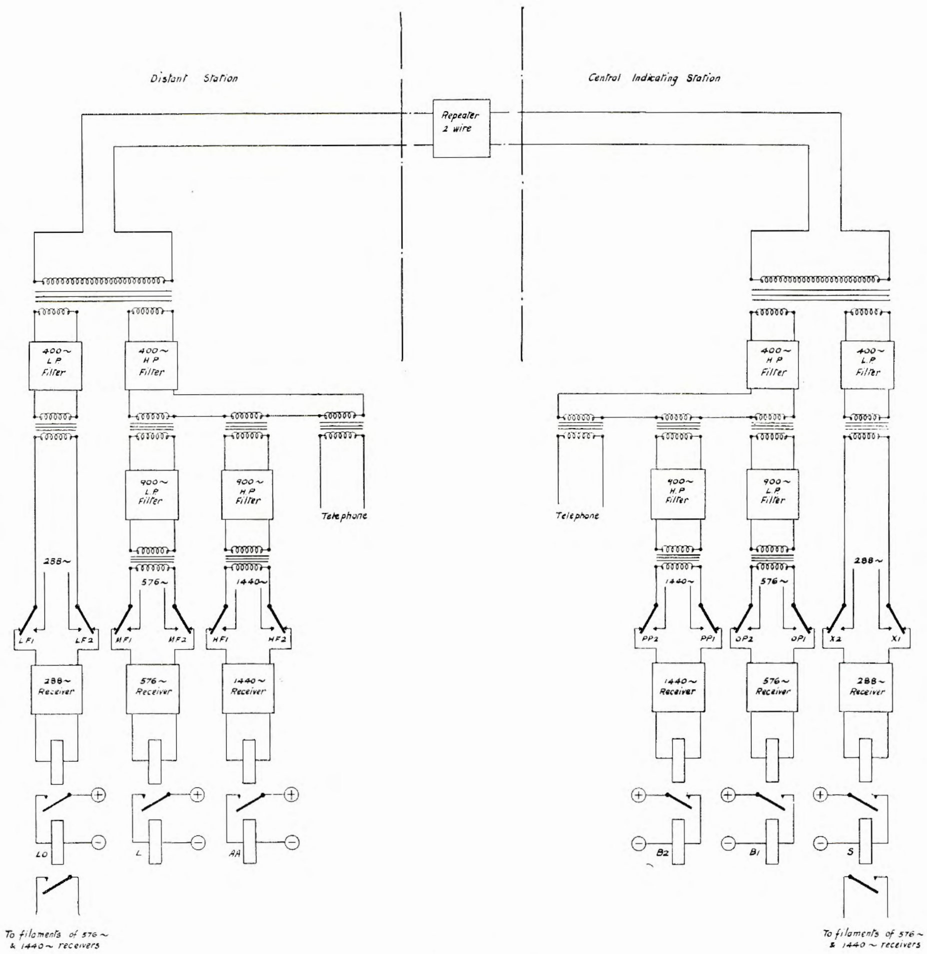

FIGURE 3

(4) Engine-room telegraph signals.

(5) kW and reactive kVA meter readings.

Thus, supposing that a circuit breaker is tripped whilst a telephonic communication is established with that particular station, the officer at the Central Indicating Station is immediately made aware of the changed condition, which causes the telephone connection to be temporarily disconnected and automatically transmits the circuit breaker signal. Only a few seconds are required to transmit the breaker signal, whereupon the telephone connection is immediately and automatically re-established.

The object of this article is not to give a detailed description of the operational features of every class of signal, but to deal only with the transmission of circuit breaker indications and meter readings by means of voice frequency currents.

LINE CIRCUIT FOR VOICE FREQUENCY SIGNALS.

Fig. 3 is a schematic diagram of the line and terminal apparatus connecting the Central Indicating Station with an outlying station through an intermediate thermionic repeater arranged to operate by voice frequency current impulses.

A small multi-frequency alternator is provided at each A.C. station to generate the three frequencies employed, namely, 288, 576, and 1,440 cycles per second. The three receivers at the ends of the line are of the amplifier-rectifier type, a sensitive relay being connected in the plate circuit of each, one receiver being provided for each of the three frequencies. By means of filter equipment, the currents of the various frequencies are confined to their respective circuits and can be employed simultaneously without mutual interference.

The actual transmission of the impulses is carried out by relays "X," "OP" and "PP" at the Central Indicating Station and by relays "LF," "MF" and "HF" at the distant stations. The filaments of the 288 cycles receivers are continually energised, so that the application of the lowest frequency at either end of the line by the operation of relays "X" or "LF," closes the filament circuits of the 576 and 1440 cycles receivers, in preparation to repeat the subsequent trains of impulses to relays "L" and "AA" or "B1" and "B2" respectively. These latter relays in turn control the stepping action of the rotary switches of the "Strowger" selective apparatus, as explained later.

Circuit Breaker Indications by Impulses of Voice Frequency Currents.

Each circuit breaker at the distant station is provided with a small auxiliary two-way switch, corresponding to the "in" and "out" positions, and a pair of Strowger relays of the latched type, which is a slightly modified form of line and cut-off relay. The local connections are shown in Fig. 4, the various pairs of relays forming a group connected in series with the slow releasing relay "CS," which operates immediately any change occurs on the circuit breakers. Each pair of relays has two coils, *a* and *b*, and two armatures, which are interlocked by a lever and arranged so that a transient energisation of coil *a* causes the *a* springs to be actuated and remain so until coil *b* is subsequently energised, whereupon the *a* springs are released.

Assuming now, in Fig. 4, that any circuit breaker is transferred to the "in" position, the *a* coil of corresponding relay "LG," together with the common relay "CS," will be energised in series with the *a* contacts. Due to the *a* windings of the "LG" relays being fitted with copper slugs, and also to a slight follow-up action of the contact springs, the slow release relay "CS" pulls up for a period of about 50 milliseconds. If the circuit breaker is restored to the "out" position, relay "CS" is again momentarily operated and the *a* springs

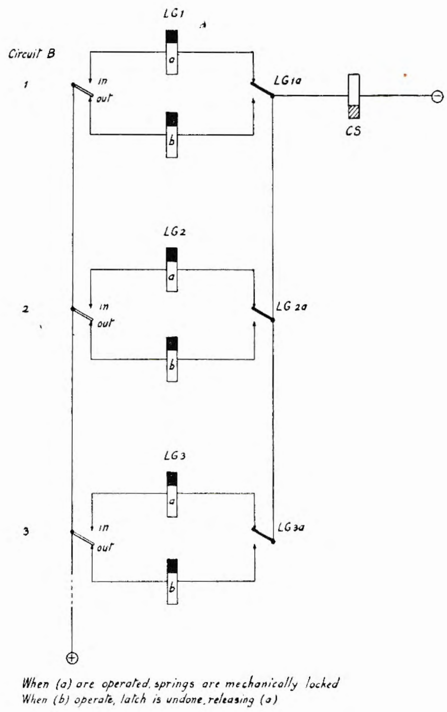

Figure 4

are restored to normal, due to the latch being released. It will therefore be appreciated that, whenever a change occurs on the circuit breakers, relay "CS" is momentarily operated.

Referring now to Fig. 5, the momentary operation of contacts "CS" completes a circuit, via wiper "D1," for relay "RSR," which locks up through its own contacts. As circuit breaker signals have priority over all other signals and communications, the operation of relay "RSR" breaks down any settings of the selective apparatus that may for the time being exist, and simultaneously closes the circuit for relay "LF" and relay "F," via operated contacts "RSR" and normal contacts "GA," "G," and "CO."

Relay "LF" operates to apply 288 cycles to the line, which in turn operates relay "S" at the

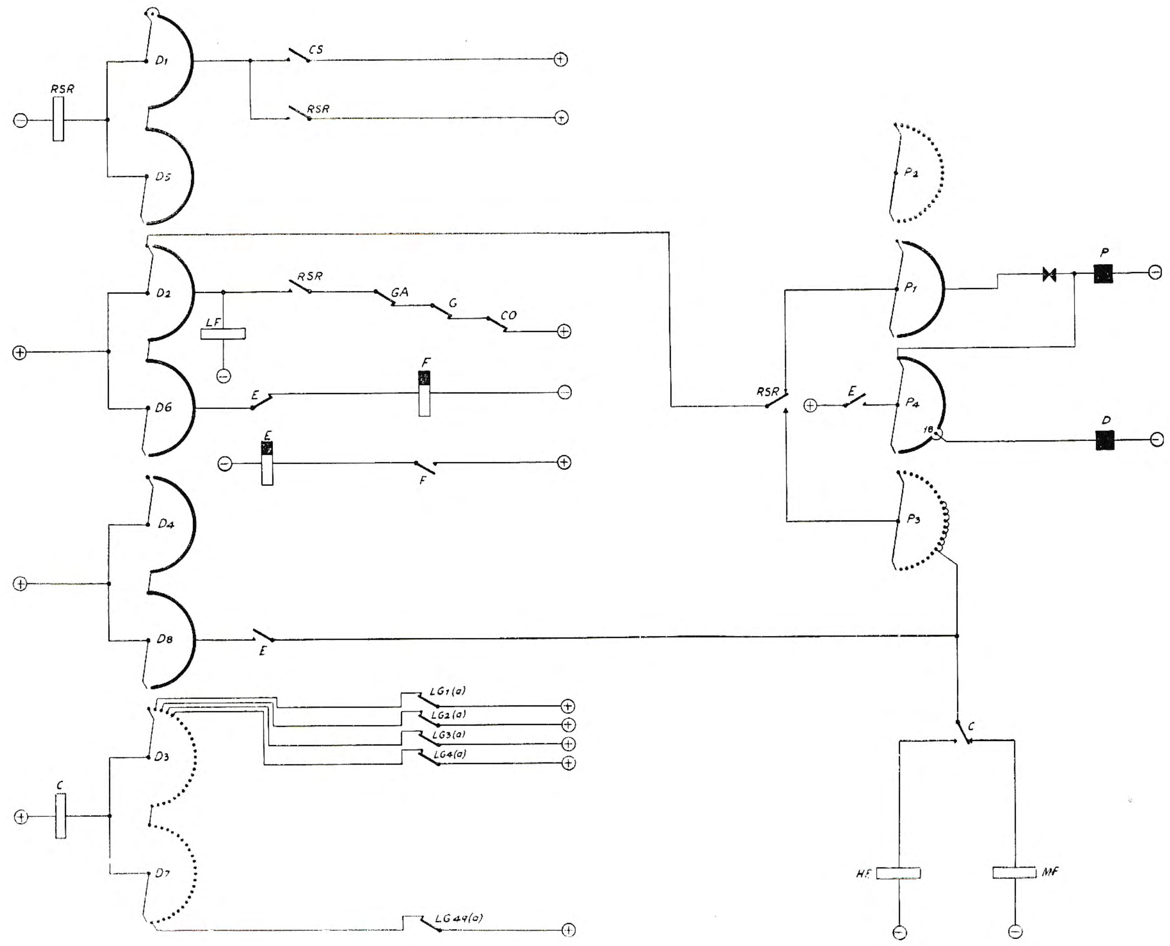

FIGURE 5

Central Indicating Station—see Fig. 3—thus preparing the two impulse receivers to accept voice frequency impulses.

The circuit for relay " F " is in series with the break contacts of relay " E," which is energised by the make contacts of relay " F." Consequently, relays " F " and " E " oscillate, the rate of oscillation being slowed down, due to the copper slugs on their windings, to about 10 operations of each per second. This oscillating feature is utilised to control the stepping actions of rotary switches " P " and " D," a make contact of relay " E " being employed for the purpose.

The first 17 operations of relay " E " cause rotary switch " P " to be stepped to the 18th contact, via wiper " P4," whereupon subsequent operations of " E " are transferred to step the rotary switch " D." At the completion of the 18th operation of " E," rotary switch " D " is stepped to the second contact, thus breaking the locking circuit of relay " RSR " at wiper " D.1.". Relay " RSR " therefore releases and the circuits for relays " LF " and " F " are transferred to wiper " D2." The stepping action of rotary switch " D " is thus continued until this switch has made one complete revolution, whereupon the circuit for relay " F " is disconnected at wiper " D2 "— thus causing the oscillation of relays " F " and " E " to cease, completing the " homing " circuit for rotary switch " P " via interrupter springs, " P 1 " bank and wiper, normal " RSR " and first contact and wiper of " D 2." The selective apparatus is thus returned to normal in readiness to transmit subsequent signals.

Considering now the manner in which the signal impulses are transmitted to the Central Indicating Station, it will be observed that rotary switch " P " will take approximately one second in which to arrive at the 10th contact, thus allowing the filaments of the medium and high frequency receivers at the distant end to have heated up sufficiently to accept impulses. Upon wiper " P3 " reaching the 10th contact, a circuit for relay " MF " is completed via normal contacts of relay " C," " P3 " bank and wiper, operated contacts of relay " RSR," first contact of bank " D2 " and wiper " D2." Relay " MF " operating, superimposes 576 cycles on the line—see Fig. 3—until the completion of the 18th operation of " E," whereupon rotary switch " D " is stepped to the second contact and relay " RSR " releases via wiper " D1," thus also releasing relay " MF," disconnecting the 576 cycles from the line. If, now, circuit breaker No. 1 is "out," a circuit for relay "C" will be closed via wiper " D3," on the second contact, and normal " LG1 " (*a*) contact springs. At the same time a circuit is prepared via wiper " D4," on the second contact, and operated contacts of relay " C," so that when relay " E " next operates, relay " HF " is actuated to superimpose 1440 cycles on the line. If, on the other hand, No. 1 circuit breaker had been in the " in " position, relay " C " would not have operated and relay " MF " would therefore have operated instead of relay " HF." When, now, relay " E " next releases, rotary switch " D " is stepped to the third set of contacts and the position of circuit breaker No. 2 is similarly checked, relay " MF " operating if in the " in " position and relays " C " and " HF " operating if in the " out " position. The other circuit breakers, also transformer tap changing switches (but in a slightly different circuit) are similarly checked in succession, as rotary switch " D " is stepped round the bank.

The corresponding operations of the apparatus controlling the indicating lamps and common alarm signal at the Central Indicating Station will be gathered from a consideration of Fig. 5.

It will be remembered that the first impulse train sent from the distant station was a long one of 576 cycles, and was applied when rotary switch " P " reached the 10th contact, and terminated at the first step of rotary switch " D," when relay " RSR " released. Simultaneously with the termination of this preliminary impulse, relay " B1 " at the Central Indicating Station also releases, causing rotary

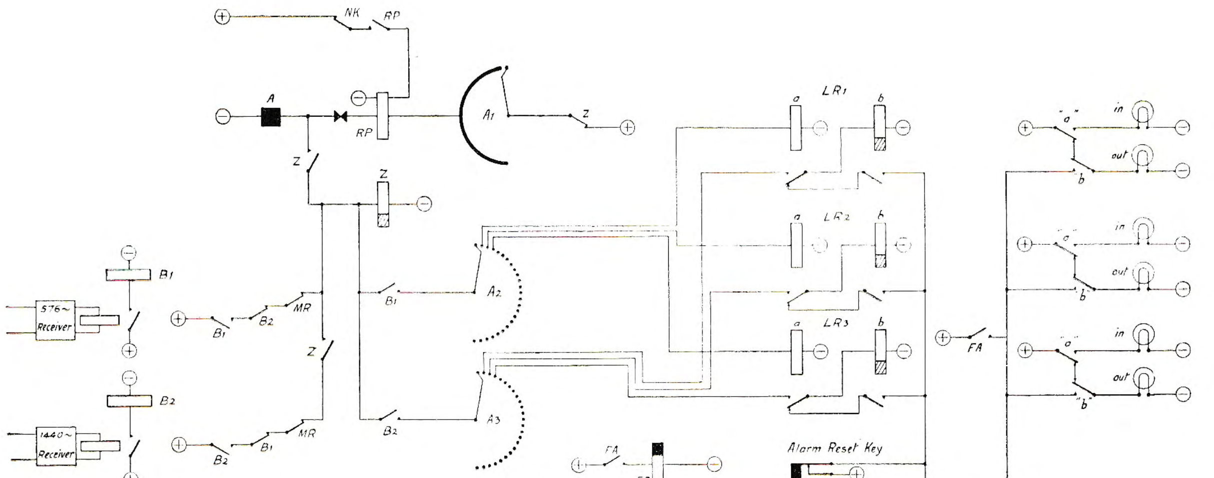

FIGURE 6

switch " A " to step to the second set of contacts. Thus the two rotary switches, " D " at the distant station and " A " at the Central Indicating Station, are in step and remain in step for one complete revolution.

Pairs of latched relays controlling " in " and " out " indicating lamps, are connected to the banks of rotary switch " A," the *a* coils being connected to the " A2 " bank and the *b* coils—copper slugged—to the " A3 " bank. Consequently, as the two rotary switches are stepped to the " out " position to flicker until the attendant restores the alarm reset key. This feature is achieved through the instrumentality of contacts fitted to relay " FA," which commences to oscillate with relay " FB " immediately the first impulse is received from the distant station, due to relay " Z " operating and causing relay " CB " to operate and lock up through the contacts of the alarm reset key. It will be observed that the " flicker " signal is not applied to any " out " lamps of

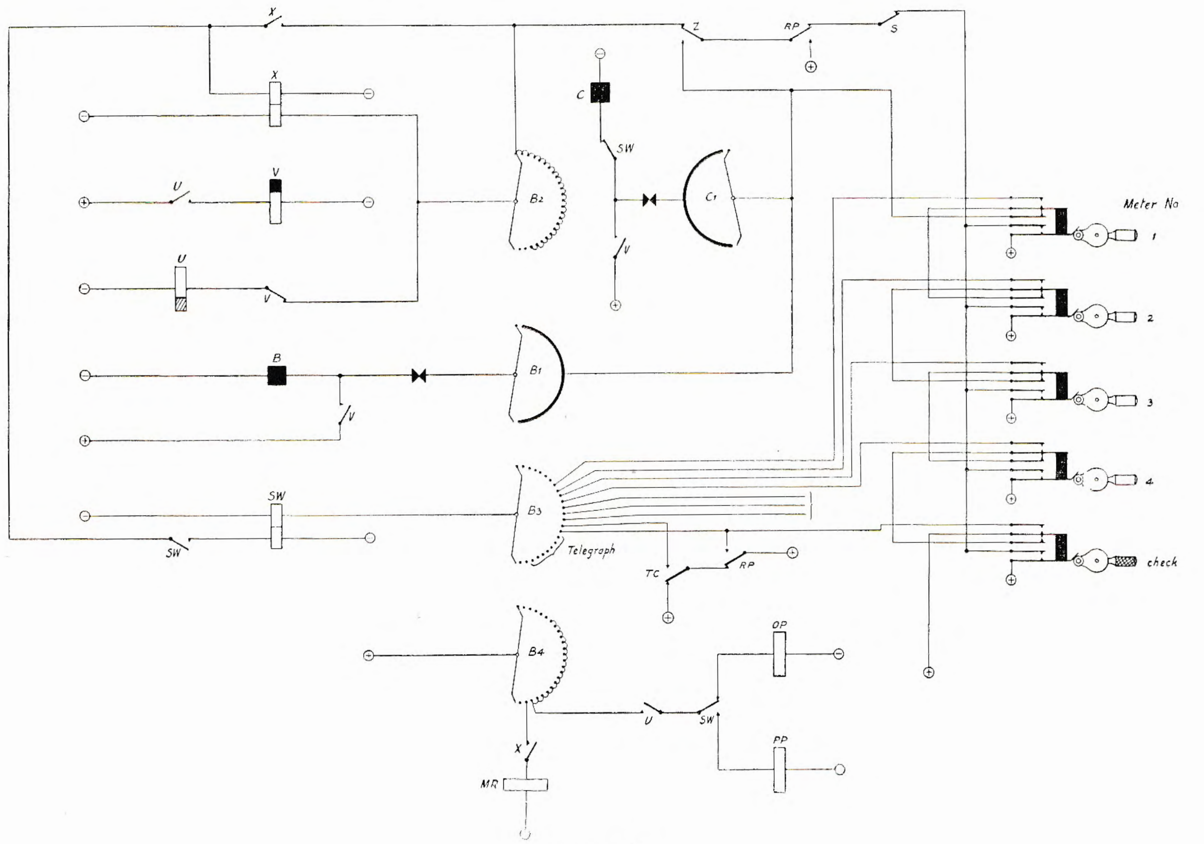

FIGURE 7

round the bank, the pairs of relays at the Central Indicating Station are operated in succession, the *a* coils being energised to latch the *a* springs as each " in " impulse (576 cycles) is received and the *b* coils being energised to release the latch and lock up through their own contacts as each " out" impulse (1440 cycles) is received.

A special feature of the indicating lamp circuit is that of the " flicker signal," which causes the lamps corresponding to any circuit breakers that have changed from the " in " circuit breakers that were not in the " in " position at the previous rotation of rotary switch " A," or to any " in " lamps.

Fifteen signal lamps (not shown in the diagram) are also provided for each transformer tap changing switch, which has fifteen separate taps. The rotation of rotary switch " D " at the distant station causes these lamps to be checked in the same manner as the circuit breaker lamps, the flicker signal being applied to the lamps corresponding to the old positions of the tap changing switch.

Upon the alarm reset key being momentarily actuated, relay " CB " is released to disconnect the alarm bell circuit and also the flicker circuit, whereupon the lamps associated with the new positions glow steadily.

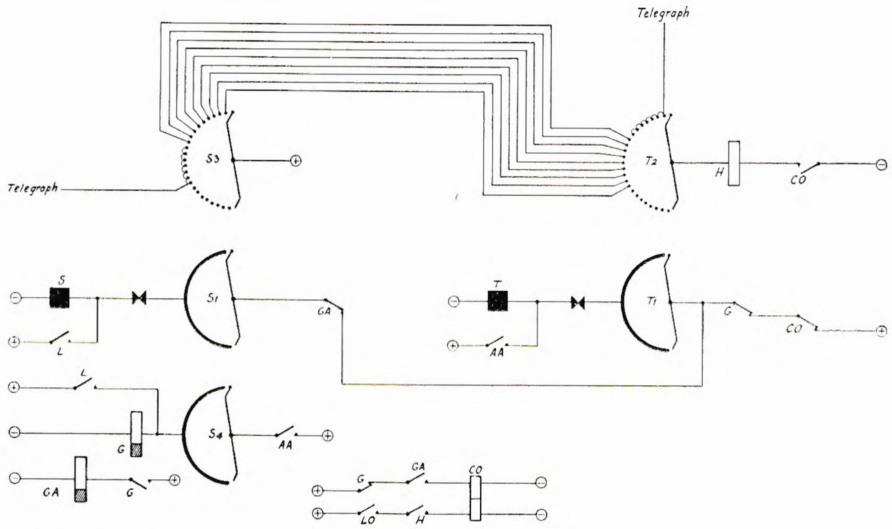

FIGURE 8

METER READINGS BY IMPULSES OF VOICE FREQUENCY CURRENTS.

At the Central Indicating Station are provided a number of mechanical meters and corresponding selecting keys of the ordinary telephone type. The mechanical meters have mainly central zero scales and consist of two Strowger rotary switch movements, arranged to actuate the pointer in opposite directions through the intermediary of differential gearing. In general, two instruments are provided for each station, one being scaled to indicate true power, " MW," the other indicating the reactive component in " MVA." For the generating stations, an instrument is also supplied to indicate the total load at the particular station.

When it is desired to read a meter at a distant station, the corresponding key at the Central Indicating Station is actuated to make the necessary " selection," through the intermediary of the Strowger selective apparatus. The selective process is accomplished in a period of about two seconds, whereupon trains of impulses are transmitted under the control of Midworth repeaters, to actuate the mechanical meter, the number of impulses being proportionate to the quantities being indicated. When the selecting key is released, or if a signal of higher priority is meanwhile originated, the selective apparatus at both ends is cleared down and the pointer of the mechanical meter " homed " to zero through the interrupter springs.

Figs. 7 and 8 show the selecting circuits at the Central Indicating Station and distant station respectively. Assuming that meter key No. 1, Fig. 7, be actuated, relay " X " operates via wiper " B2 " and locks up through its own contacts, via the normal contacts " Z," " RP," and " S." Relay " U " also operates via the same channel and normal contacts of relay " V," which is in turn operated by relay " U." The two relays " U " and " V " therefore oscillate and, being slugged with copper, the rate of oscillation is slowed down to about ten operations of each per second. The oscillating contacts of relay " V " are employed to step rotary switches " B " and " C," which proceed step-by-step round the banks until the eighth sets of contacts are reached, whereupon relay " SW " operates and locks up to arrest rotary switch " C," whilst rotary switch " B " proceeds until its wipers rest on the 24th set of contacts. It will be observed that the circuit for relay " SW " was closed via wiper " B3," 8th contact of bank " B3 " to positive via operated meter key No. 1. If, of course,

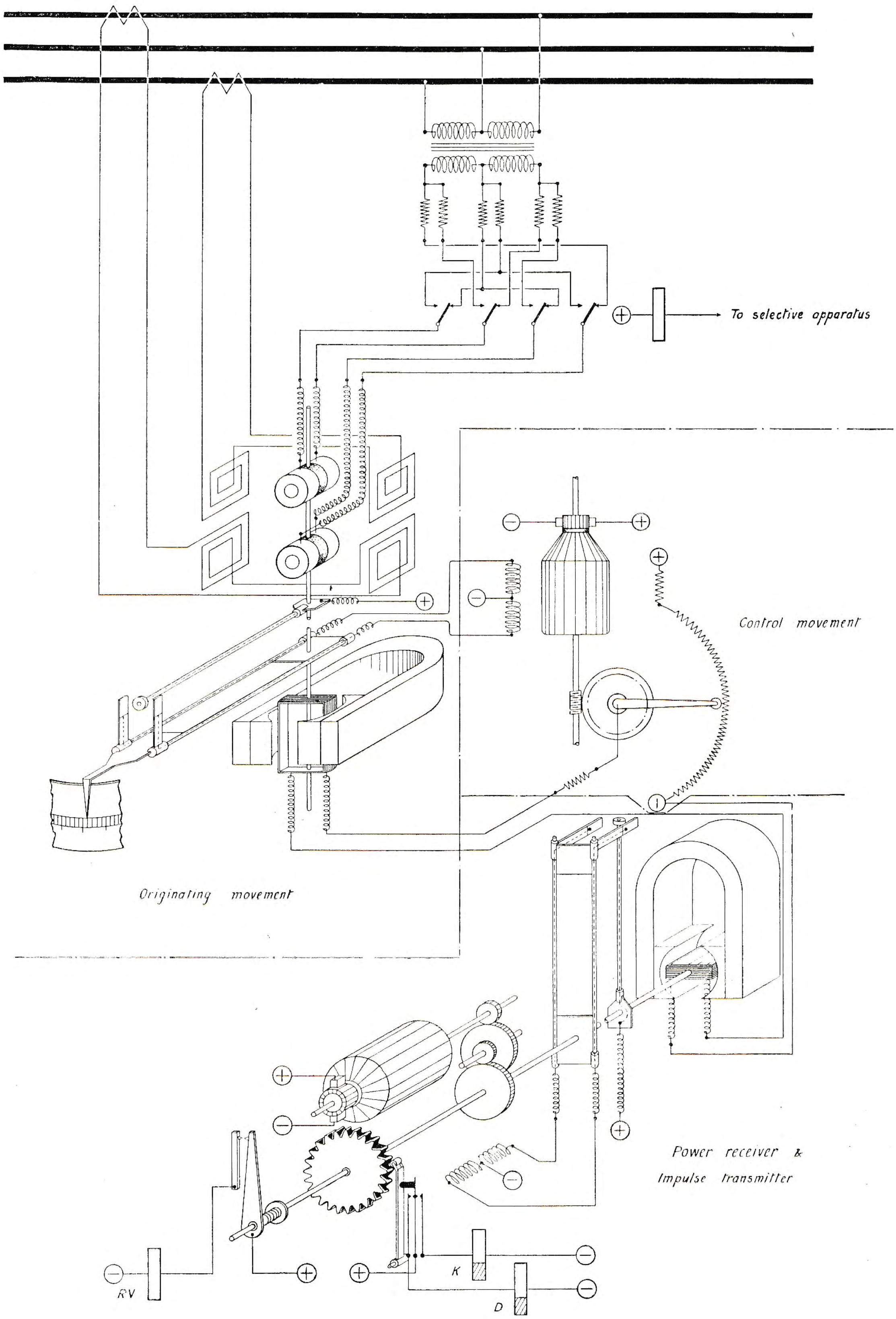
To selective apparatus
Control movement
Originating movement
Power receiver &
Impulse transmitter
RV
K
D

FIGURE 9

any other meter key had been actuated, the operation of relay " SW " would have been delayed until the corresponding contacts of bank " B3," and also of bank " C," had been reached.

Reverting now to the point where relay " X " first operated, and referring to Fig. 3, it will be observed that 288 cycles was imposed upon the line, thus operating relay " LO " at the distant station and so preparing the medium and high frequency receivers to accept impulses. Rotary switch " B " reaches the 7th set of contacts in about three-quarters of a second, whereupon relay " OP " is operated via normal contacts of relay " SW," operated pulsing contact " U " and wiper " B4." The operation of relay " OP " superimposes an impulse at 576 cycles upon the line. As meter key No. 1 has been assumed to be actuated, relay " SW " operates and locks up at the next step of rotary switch " B," so that relay " PP " operates to transmit an impulse of 1440 cycles on each of the remaining sets of contacts up to and including the 23rd. Thus one impulse of 576 cycles and 16 impulses of 1440 cycles are transmitted to the distant end. Rotary switch " B " continues to the 24th contact, whereupon relay " MR " operates to prepare the circuit to the particular mechanical meter, further stepping action being arrested by the disconnection of the circuit for relay " U " at wiper " B2," now on the 24th contact.

It will be observed from Fig. 3 that the single impulse of 576 cycles actuates relay " L." When relay " L " releases, rotary switch " S "—see Fig. 8—is stepped to the second contacts. The sixteen subsequent impulses, 1440 cycles, actuate AA, thus stepping rotary switch " T " to the 17th contacts. The circuit is now completed for the cut-off relay " CO " as follows :—

The slow release relays " G " and " GA " are both maintained operated during the impulsing period via the pulsing contacts of either relay " L " or relay " AA." At the conclusion of the impulses, relay " G " releases about 200 milli-seconds before relay " GA." The circuit for the upper winding of relay " CO " is thus completed, causing that relay to operate and close the circuit for relay " H," via wiper " S_3 " and 2nd contact, the 17th contact of bank " T_2 " and wiper. Relay " CO " therefore locks up through its lower winding and the operated contacts of " H " and " LO," the latter being steadily operated due to the 288 cycles being on the line from the Central Indicating Station. The circuit is now switched through to the Midworth repeating apparatus, which proceeds to transmit the actual metering impulses to the mechanical meters at the Central Indicating Station.

Before consideration is given to some details of the Midworth repeating apparatus, it should be observed that the selection of the various meters is attained by variations in the sequence of the impulse trains, determined by the particular meter key actuated. Thus, supposing that meter key No. 7 is actuated, seven impulses of 576 cycles and ten impulses of 1440 cycles are transmitted. This particular combination would set rotary switch " S " on the

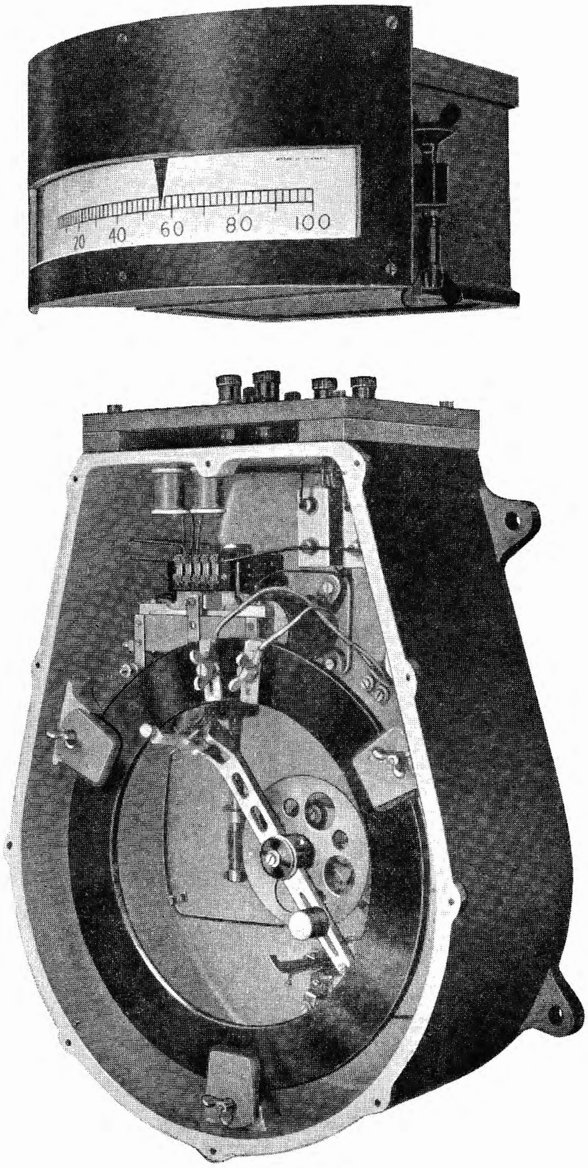

FIGURE 10

8th set of contacts and rotary switch " T " on the 11th set of contacts, thus completing the circuit for relays " H " and " CO " as above.

Midworth Repeater Apparatus.

The Midworth repeater apparatus, as applied to the Scottish "Grid," is employed for metering readings only, the general arrangement being shown diagrammatically in Fig. 9. This apparatus consists essentially of—

(*a*) Originating movement ;

(*b*) Control Movement ;

(*c*) Power receiver and impulse transmitter.

A typical Midworth originatory movement and central movement are shown in Figure 10. In Fig. 9, the originating movement is that of a wattmeter of the unbalanced load type, arranged to indicate either true power or reactive kVA, depending upon whether the relay is normal or operated. The moving element carries a platinum contact disc instead of the usual indicating pointer, as the latter, together with two insulated contact surfaces, one on either side of the contact disc, are carried by the spindle of the moving coil element. Variations in the power being indicated, move the disc against either of the side contacts, energising the field of the small motor and causing the armature to revolve in alternate directions. The armature continues to revolve until the moving coil element is energised sufficiently to separate the disc and side contacts, as determined by the position on the potentiometer of the roller contact arm, which is driven from the armature shaft through worm gearing.

The spindle of the power receiver moving coil carries a contact disc similar to the above, which operates between the two insulated contact surfaces carried by a separate spindle geared to the armature of the power receiver motor. As the moving coils of the originating movement and power receiver are identical, and are specially constructed to follow the same scale law as the wattmeter, it follows that the control imposed upon the power receiver motor is strictly proportional to the wattmeter indications. Furthermore, it will be appreciated that this remains true even if variations in voltage occur, or if the resistance of the circuit connecting the control movement with the power receiver is altered.

The spindle of the power receiver that carries the two insulated side contacts, also carries an interrupter wheel and a friction driven contact arm. The interrupter wheel actuates a set of three impulsing springs, controlling two slow release relays " D " and " K," whilst the friction driven contact arm energises relay

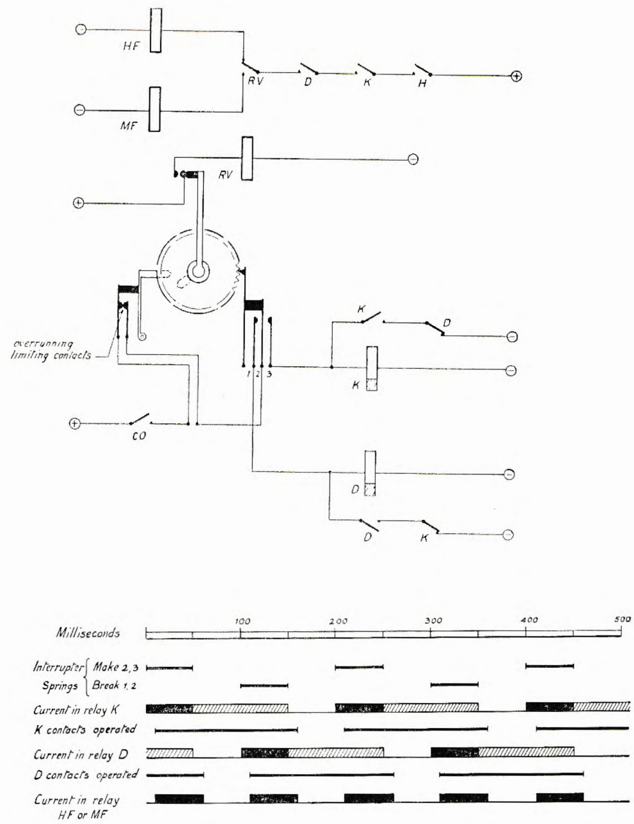

FIGURE 11

" RV " when the spindle rotates in one direction, but not when the spindle rotates in the other. The interaction of these relays will be gathered from a consideration of Fig. 11, which is a schematic of the actual metering impulse transmission circuit.

Normally, the power receiver is disconnected and is therefore at rest in the zero or home position. At the completion of the selective operations, the power receiver is switched into circuit and, provided that the meter being read is off zero, the motor of the power receiver commences to rotate in one direction or the other, as determined by the particular reading. The speed of rotation of the interrupting wheel is adjusted so that the number of complete operations of the interrupter springs is about five per second.

It will be remembered that relay " H " and relay " CO " are already operated, thus preparing the impulsing circuit. Relays " D " and " K," therefore, operate alternately, and, being of the slow releasing type, there are two periods in each complete cycle of operations of the interrupter springs, in which the contacts of both relays will be actuated. This will be clear from a consideration of the timing diagram.

It will therefore be seen that either relay " HF " or relay " MF " is operated alternately, as determined by the operation of relay " RV," to transmit two impulses of 1440 or 576 cycles respectively, for each complete cycle of operations of the impulsing springs.

Considering now the operation of the mechanical meter—Fig. 12—which has already been selected at the Central Indicating Station, and remembering that relay " MR " is in the operated position, it will be seen that relay " B2 " will operate at each impulse of 1440 cycles and so energise winding " A " of the mechanical meter to operate the pointer in a clockwise direction. Similarly, relay " B1 " will operate at each impulse of 576 cycles to energise winding " B " to operate the pointer in an anti-clockwise direction. The mechanical meter therefore keeps in step with the transmitted impulses from the outlying station and follows the indications of the meter being read, so long as the meter key is depressed and provided no signals of higher priority are initiated in the meantime

Upon completion of a meter reading, the meter key being restored, or upon a signal of higher priority occurring, the homing circuit of rotary switch " C " is completed via wiper " C1 " and contacts " SW," which become normal, thus disconnecting the metering circuit. The homing circuit of the mechanical meter is then completed via the first bank contact and wiper " C1," to restore the mechanical meter to zero.

The foregoing notes do not pretend to explain the complete indicating system as employed by the Electricity Board. Many features have been entirely omitted and for the sake of simplicity, all contacts not obviously required for the two particular classes of signals considered in this article are not shown in the diagrams. Also, the whole of the apparatus employed to prevent the possibility of wrong signals being given is not shown, although actually false indications are rejected by the

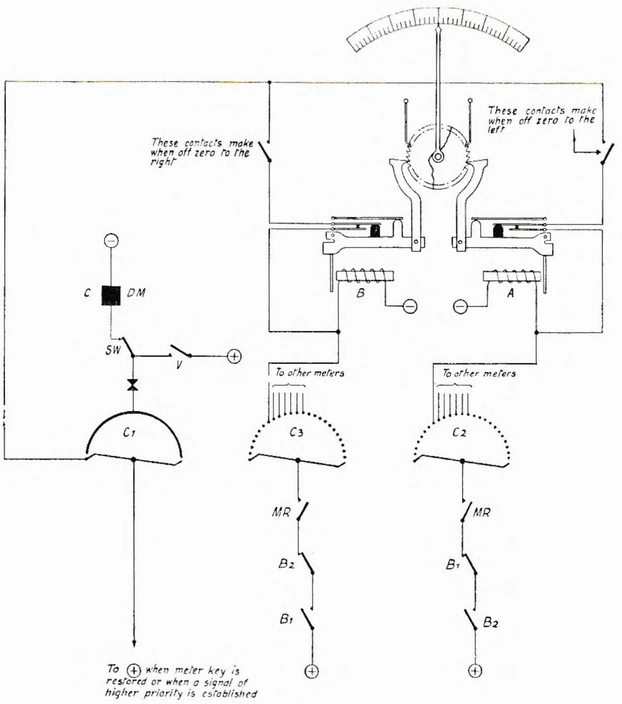

FIGURE 12

station concerned and the cycle of signals automatically repeated. A typical example of this feature is the function of relay " RP," see Fig. 6, the operation of which is described below.

It will be observed that the accuracy of the circuit breaker signals is dependent upon switch " D " at the sub-station and switch " A " at the Central Indicating Station being stepped in unison and means are provided whereby any departure from unison, which would lead to wrong signals being given, is automatically discovered and a full cycle of check indications immediately then commenced.

At the Central Indicating Station, during the time that impulses for circuit breaker indications are being received from the sub-station, relay " Z "—see Fig. 6—remains steadily operated and releases upon completion of the full cycle of operations. If, for any reason, the switches at the two stations become out of step, switch "A" will be off normal when " Z " releases and,

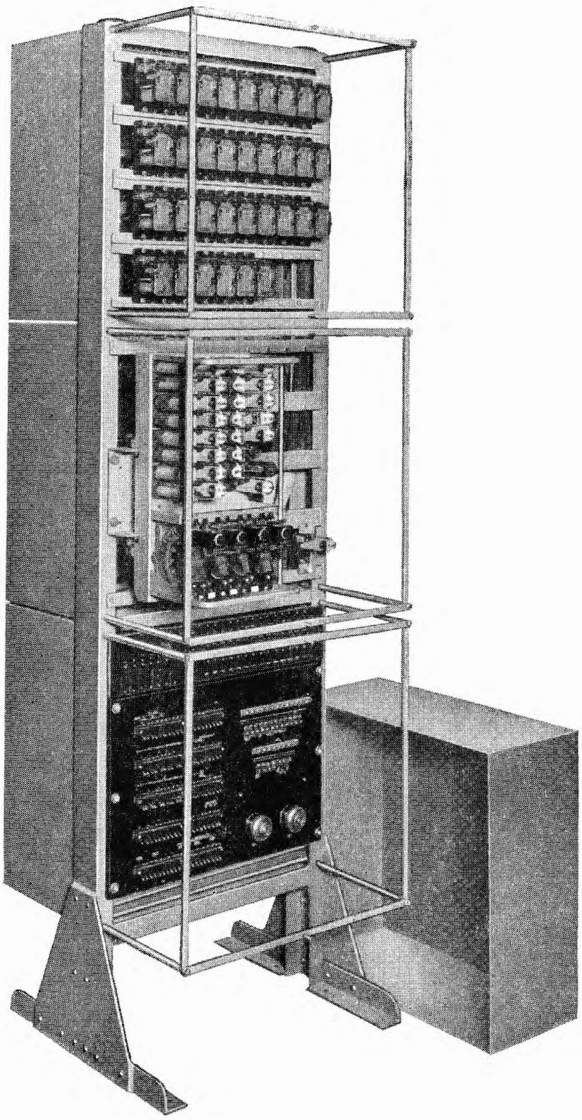

FIGURE 13

consequently, this switch "homes" to normal via one winding of relay "RP," which locks up through its own operated contacts and the normal contacts of relay "NK." Referring now to Fig. 7 it will be observed that the operation of relay "RP" actuates relay "X" via bank "B2" and marks the check wire on bank "B3." Switch "B" therefore rotates and causes trains of impulses to be transmitted over the line to the sub-station, where switches "S" and "T"—see Fig. 8—are rotated to the 10th and 9th sets of contacts respectively. Relays "CO" and "H" are in turn then operated and the operation of relay "H," which in addition to operating relay "RSR"—see Fig. 5—to re-commence the cycle of circuit breaker indications, also actuates a further relay, not shown. This latter relay applies a combined impulse of 576 and 1440 cycles to the line to operate a relay "NK" at the Central Indicating Station, where relay "RP" is then released before the impulses corresponding to the circuit breaker indications are received. This automatic checking action is repeated in the event of any departure from unison occurring persistently, thereby drawing attention to any possible defect that may affect the accuracy of the signals.

Figure 13 shows the general arrangement of the Strowger apparatus for an outlying station.

An article describing the engine-room telegraph, telephone communications and priority feature, together with illustrations of the apparatus and switchboards, will be given in a subsequent issue.

For permission to publish the above we are indebted to the Commissioners of the Central Electricity Board.