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Paper 32

Power Supply: Remote Control of Power Distribution

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1 Introduction

To ensure continuity of power supply to the tracks of electrified railways it is necessary to have a comprehensive picture of supply conditions and the means to operate switchgear with a minimum of delay, at all the feeder stations and track sectioning cabins. The electrified lines are therefore divided into Electric Control Areas, each with its Electric Control Station. An area may comprise 40 or 50 controlled stations. With the greater distances between feeding points made possible by the adoption of the 25 kV A.C. system, the most distant station may be 60 or 70 miles from the Control Station, which may exercise control of six or seven hundred items concerned with the power supply to some 600 single track miles.

From the Control Station, comprising Control Room, Apparatus Rooms, Battery Rooms and accommodation for ancillary facilities, control is exercised by a supervisory remote control system using telephone type equipment similar to that used by the British Post Office and the Central Electricity Generating Board for their control systems.

Figs.1, 2 and 3 show the Control Areas for lines at present authorised. Contracts have been let for the provision of the supervisory equipment for the Crewe and Cathcart Areas to the Automatic Telephone and Electric Co. Ltd. and for the Romford and Pitsea Areas to Standard Telephones & Cables Ltd.

It is to be noted that, although equipment has been supplied by two contractors and there are certain differences between their methods of accomplishing what is required, the equipment has been so specified that a control operator can operate equipment supplied by either contractor with equal facility. The advantages of this will become the more marked as electrification of the main line extends to such an extent that Control Areas equipped by different contractors are no longer isolated from one another by non-electrified lines. An important degree of standardisation has thus been effected between the Commission and the Contractors concerned.

2 General Description

The Control Room accommodates a mimic diagram of mosaic tiles on which are represented the power supply system and the trackwork of the Area (fig.4). The use of mosaic tiles facilitates the modification of the diagram when alterations and additions are made to the traction system. Each controlled circuit breaker and motorised switch is represented on the diagram by a twist type discrepancy switch, the knob of which is translucent with a bar across it. The bar lines up with the feeder or overhead line, to signify the closed position and lies across it for the open position. A lamp, integral with the switch, illuminates the knob whenever the position of the switch does not agree with that of the circuit breaker or switch which it represents, i.e. when there is 'discrepancy'.

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Adjacent to the representation of each station are common switches and lamps for the following purposes:—

Operating circuit breakers and switches
Accepting and cancelling alarms
Checking indications
Testing the indicating lamps
Operating and indicating a 'dummy circuit breaker'

The dummy circuit breaker is a test feature whereby a relay at the controlled station is made to simulate a circuit breaker, so providing a means of checking the operation of the supervisory signalling system without operating an actual circuit breaker.

Alarm lamps, together with an audible alarm, are provided for:—

Loss of main and standby supplies to the Railway Signalling System
Loss of switchgear protection normal reference voltage
Buchholz alarm
Cable low pressure alarm
Common station alarm
Station supervisory fault alarm

The control desks, facing the diagram, accommodate a telephone switchboard, metering facilities, line changeover switches and line alarms.

The telephone type relays and uniselectors, operated by the switches on the diagram, are mounted on jack-in groups in cubicles in the apparatus rooms. Complementary equipment is provided at each feeder station and track sectioning cabin (fig.5).

Signal transmission is by pilot wires, one pair for outgoing operating signals and one pair for incoming indication signals. Up to twelve stations can be served by one set of four pilot wires, such a group being termed a 'system' (fig.6). The pilot lines are duplicated and line changeover equipment is provided. Additional pairs are provided for telephone speech circuits.

3 Supervisory Signalling

The control and indication of the positions of the circuit breakers and switches require the transmission of information over the pilot cables between the Control Station and the feeder stations and track sectioning cabins and this can be done by means of coded pulses. A simple method of obtaining these from a battery is to apply positive/negative to the line to provide a 'positive' pulse and negative/positive to provide a 'negative' pulse. In this way a train of n pulses, each of which may be either positive or negative, can, with the use of polarised relays and suitable decoding apparatus, present 2^n combinations and therefore 2^n sets of information.

The use of D.C. signalling in association with a railway electrified on the A.C. system is impracticable except in exceptional cases over short distances both because of the possibility of mutilation of the codes by voltages induced on the pilot cables by the traction system current and because of the attenuation over the distances involved. Recourse is had, therefore, to A.C. signalling which permits the use of amplifiers at intervals along the line and the use of isolating transformers which limit the level of induced voltage and isolate the apparatus from this voltage. The frequencies used for the signalling are within the voice frequency range (400 c.p.s. to 4,000 c.p.s.) and outside the range of those harmonic frequencies which are present in the traction system current to a sufficient degree to be liable to induce appreciable voltages on the pilot cables.

With D.C. signalling three line states are possible, namely positive, negative and zero so that the individual pulses, either positive or negative can be separated by intervals of no signal on the line. With A.C. signalling some method has to be adopted of obtaining two different types of pulse to replace the positive and negative used in D.C. signalling, with a suitable means of separating like pulses.

4 The Method Using Two Frequencies

The Automatic Telephone and Electric Co. Ltd. have adopted the use of two frequencies. One frequency common to all stations is used together with a second frequency which is particular to the station concerned.

The code used is then as follows:—

(i) Station and common frequency are applied to the outgoing pair of the line and, being received at the station concerned, cause a station frequency to be returned by the incoming pair to the Control Station so indicating that the correct station has been selected.

(ii) Common frequency is removed from the outgoing pair and an impulse code is sent out to select the group which includes the device which it is desired to operate. This code consists firstly of from one to three pulses at station frequency followed by the necessary number of pulses at common frequency to make up a total of four pulses.

(iii) Without any break in the impulse train, the requisite number of station frequency pulses to select the desired device in the group are sent out followed by sufficient common frequency pulses to make a total of 25 pulses.

Hence to select any device in any station a total of 30 pulses is transmitted made up of:—

1 pulse to select the station
4 pulses to select the group of devices
25 pulses to select the device in the group

The device having been selected, station frequency remains on the line from the Control Station and also, depending upon the position of the selected device, station or common frequency from the station to hold the selection and connect the operating switches into circuit. The outgoing frequency from the Control Station is connected to the line under the influence of the selecting key (a discrepancy key on the diagram for a circuit breaker or motorised switch) and of the incoming frequency. The frequency from the station is under

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the influence of auxiliary contacts on the device concerned and the frequency from the Control Station. Thus the selection hold can be discontinued, if desired, by restoring the selecting key at the Control Station. Similarly the automatic or manual operation of the device during this hold condition will, by the changeover of the auxiliary contacts of the device, discontinue the selection hold.

Operation of a 'close' operating switch momentarily interrupts the hold condition and then reapplies station frequency and operation of an 'open' operating switch momentarily interrupts the hold condition and applies common frequency. In each case the frequency is applied for approximately one second to operate the appropriate interposing relay and hence the device concerned.

As the device operates its auxiliary contacts change over and cause either common or station frequency to be sent to the Control Station, according to whether the device has moved to the open or the closed position and this removes the discrepancy condition, cancels the selection and restores the equipment to normal ready for the next operation.

When a device at a station operates automatically or is operated locally, the station sends station frequency to the Control Station where the apparatus replies with both station and common frequency. The common frequency guards against interruptions from other stations and the station frequency permits the station concerned to send an impulse train. This train consists of three consecutive portions which indicate respectively the station calling, the group containing the device which has operated and the positions of all the devices in that group. The impulse trains always comprise a fixed total number of pulses which number is checked at the Control Station. If for any reason the incorrect number is received a re-check is performed.

This method of signalling is illustrated in fig.7 and it will be seen that the total time for selection is approximately four seconds and for indication approximately five seconds.

5 The Method Using One Frequency

Standard Telephones & Cables Ltd. use a frequency modulated system wherein the pulses are transmitted by modulating the single basic frequency. The two line conditions provided by this method of signalling are derived by a shift of the fundamental frequency F to give two states corresponding to F+30 and F−30. The one condition is referred to as 'mark' and the other as 'space'. However, it is not practicable to regard 'mark' as a complete 'positive' pulse and 'space' as a complete 'negative' pulse because a train of like pulses would constitute a steady condition and there would be no means of counting the pulses. Instead, therefore, a 'positive' pulse is taken as consisting of 75 per cent mark and 25 per cent space whilst a 'negative' pulse is taken as 75 per cent space and 25 per cent mark. It will be seen that in a 'positive' pulse there is a change from mark to space and in a 'negative' pulse there is a change from space to mark. It is really these 'opposite direction' changes which enable the pulses to be distinguished from each other and to be counted. The principle of the method is indicated in fig.8.

The code used is as follows:—

(i) A pulse to seize the station concerned.

(ii) A train of four pulses of which any one may be 'positive' or 'negative' to select the group containing the device which it is desired to operate.

(iii) A train of four pulses of which any one may be 'positive' or 'negative' to select the desired device within the group.

(iv) A train of 'negative' pulses to hold the selection whilst the Control Station apparatus, having received a check-back signal from the station, checks that the station has received the correct code.

(v) Four pulses to differentiate between 'close' and 'open' signals, i.e.

Close + + − −

Open + − + −

(vi) A 'positive' pulse train of two seconds duration to effect the operation.

When a device at a station operates automatically or is operated locally, the station apparatus transmits a train of pulses which indicates both the group in which the change has taken place and also complete information concerning all the switchgear items in that group. The total time for selection, preparatory to control operation, is approximately four seconds and for indication following automatic operation the average time is three seconds, varying from two to five seconds.

6 Pilot System

One duplex channel is allocated for each station with an additional channel from each station from which supply voltage readings are transmitted back to the Control Station.

The stations are connected to the duplicated 4-wire pilot circuits in such a way as to ensure that the loss of any line has the minimum effect on the supervision and control of the electric traction supply system. The grouping of stations on the line is illustrated typically in fig.6 which also shows the channel reference allocated to each station. Telephone ringing in both directions is effected by coded signals, but separate omnibus circuits are used for speech.

The voice frequency telegraph system is of the fully transistorised type, thus not only avoiding the necessity of providing special power supplies, not readily available from a 50 v. battery, but also resulting in economy of space for the equipment and reduction of heat dissipation.

Since the 4-wire lines are duplicated, provision is made to allow remote changeover of all stations on the same systems from the A to the B lines, and *vice versa*. The working line i.e. the line to which the stations are switched at any given time, is monitored and any failure indicated at the Control Station. It is possible for time switching automatically to connect A and B lines in alternate half-hours as required.

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7 Voltage Indication

The remote indication of the voltage of each high voltage supply is transmitted from the feeder stations to the Control Stations by a telemetering system. Associated with each incoming supply at each feeder station is an impulsing device controlled by the voltage from the secondary winding of a voltage transformer. In the Crewe and Cathcart Control Areas the length of impulse is a function of the value of the supply voltage. The impulse length is measured at the Control Station and causes a milliammeter scaled in volts to give the required indication when the station concerned is selected by the Control Room Operator.

In the Romford and Pitsea Control Areas the impulsing device is similar but the Impulse Modulated Telemetering System is used wherein the rate of impulsing (instead of the impulse length) is a function of the supply voltage. This telemetering system has been adopted as standard throughout the electricity transmission networks of England, Wales and Scotland and for the Kariba Scheme in South Rhodesia. Fig. 9 shows the basic circuit of the telemeter as used in the Romford and Pitsea Control Areas.

Contact MC which is operated by the impulsing meter successively charges capacitor CA and discharges it into reservoir capacitor CB connected across Amplifier 1. The latter has considerable gain and builds up a positive output potential whilst maintaining its input potential at a nearly constant value; this ensures that capacitor CA always delivers the same quantity of charge so that the average input current depends upon the frequency of operation of contact MC. The output voltage of Amplifier 1 is applied through a smoothing circuit SK to Amplifier 2, a cathode-follower, which in turn feeds the average potential to the indicating meter circuit. Part of the output is also fed back to the input via a resistance to centralise the input due to CA. Therefore, for any particular contact rate the system establishes a balance when the voltage across the meter circuit is proportional to the contact rate.

8 Maximum Demand Indication

The half-hourly maximum demand is metered at the feeder stations by taking pulses from special kilowatt-hour meters and counting these pulses over half-hourly periods using either a uniselector or relay type counting group working on an impulse coded system. These relays are connected through to the supervisory equipment and cause a meter to register the maximum demand value at the Control Station.

The maximum demand readings from the different feeder stations can be selected as required and displayed on a meter on the desk at any time during the succeeding half-hour.

9 Supervisory Telephone System

Each pilot system has at least one separate speech pair and the telephones at the stations can be connected to this line for communication purposes.

The calling from Control Station to Station and *vice versa* is by the supervisory equipment. At the Control Station the call/speak key on the particular system is thrown and the station number called. This causes the selection to be made in the supervisory equipment and rings the telephone bell at the station. Calling back to the Control Station is similar to an indication train, the calling lamp on the particular system being flashed and a buzzer sounded.

Systems can be coupled together on the desk by coupling keys.

10 Maintenance Telephone System

A local telephone system is provided linking the apparatus rooms, apparatus suites, rear of diagram and desk. Calls can be made between the diagram and apparatus rooms without affecting the desk and it is possible to extend out to the stations from this system by the coupling keys.

11 Test Equipment

At each Control Station a set of test racks is installed, equipped to be the equivalent of a Control Station and a station so that maintenance testing and preliminary staff training can be carried out independently of the operational equipment. Portable test sets each equivalent to a control station are available for the test functioning of station equipment.

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SUMMARY

The paper describes the system of remote control of power distribution adopted by the Commission for its programme of Railway Electrification on the A.C. system, by which control may be exercised from one Control Station of six or seven hundred switches and other items concerned with the power supply to some 600 single track miles, the most distant station being up to 70 miles from the Control Station.

It gives details of the control facilities provided at the Control Stations and stresses that, although contracts for the provision of the supervisory equipment have been let to two Contractors, the Automatic Telephone and Electric Co. Ltd. and Standard Telephones and Cables Ltd, the equipment has been so specified and built that a control operator can operate equipment supplied by either Contractor with equal facility.

The methods of voice frequency signalling between Control Stations and controlled stations adopted by the two Contractors and also of telemetering supply voltage and maximum demand, are described and illustrated.

The utilisation of the supervisory pilot system and the measures adopted to ensure its security, as well as those to minimise the effects of the loss of a line, are outlined.

Finally reference is made to the telephone system provided for use with the supervisory system and to the maintenance testing facilities provided.

ZUSAMMENFASSUNG

Der Bericht beschreibt ein ferngesteuertes Stromverteilungssystem, wie es von der 'British Transport Commission' im Zuge der Umstellung der Britischen Eisenbahnen auf Wechselstrombetrieb angewendet wird. Das beschriebene System ermöglicht es, von einer Zentralstelle aus die Stromzufuhr zu etwa 600 miles eingleisiger Strecke, und zu Orten die bis zu 70 miles entfernt liegen, durch ein System von 600 bis 700 Schaltern und sonstigen Steuerorganen zu regeln.

Im Einzelnen beschreibt der Bericht die von zwei verschiedenen Lieferfirmen (Automatic Telephone & Electric Co. Ltd. und Standard Telephones & Cables Ltd.) hergestellten Steuereinrichtungen und weist besonders darauf hin, dass trotz der Notwendigkeit mit zwei verschiedenen Systemen zu arbeiten, die Bedienungsmannschaften ohne besondere Schwierigkeiten beide Systeme nebeneinander handhaben können, weil dieselben äusserst günstig ausgelegt sind.

Sodann werden Einzelheiten der von beiden Lieferfirmen verwendeten Methoden der Tonfrequenz-Nachrichtenübermittlung und des Fern-Messverfahrens für Normal- und Spitzen-Stromversorgung beschrieben.

Weiters wird angedeutet, in welcher Weise das Fernüberwachungssystem ausgenützt und ständig betriebsbereit erhalten wird, und welche Massnahmen bei Ausfall einer Versorgungslinie ergriffen werden müssen, um das Ausmass der Störung in den kleinst möglichen Grenzen zu halten.

Schliesslich wird noch das Telephonsystem erwähnt, das dem Fernüberwachungssystem und den übrigen Einrichtungen für ständige Betriebskontrolle zugeordnet ist.

RÉSUMÉ

Cet exposé décrit le système de télécommande de distribution d'énergie adopté par la British Transport Commission pour l'électrification de ses chemins de fer en courant alternatif. Il s'agit d'un poste de commande comprenant 600 ou 700 commutateurs et d'autres équipements nécessaires à la distribution d'énergie pour 600 miles de voie unique, le poste commandé le plus lointain étant jusqu'à 70 miles du poste de commande.

On donne les détails des facilités de commande dont on dispose aux postes at souligne que malgré la passation de commandes à deux fournisseuers – l'Automatic Telephone and Electric Co. et Standard Telephones and Cables Ltd. – la construction de l'équipement de contrôle est telle que l'opérateur peut utiliser avec la même facilité l'équipement de l'un ou de l'autre fournisseur.

Les méthodes de signalisation à fréquence musicale entre le poste de commande et les postes commandés adoptées par les deux fournisseurs ainsi que les méthodes de télémesure de la tension d'alimentation et de la charge maximum, sont décrites et illustrées.

On donne aussi un aperçu du système-pilote de contrôle et des mesures prises pour assurer sa securité ainsi que celles adoptées pour réduire au minimum les conséquences d'une perte de ligne éventuelle.

Enfin on mentionne le système de liaisons téléphoniques prévu pour être utilisé avec le système de contrôle et les facilités procurées pour les essais d'entretien.

RESÚMEN

Este artículo describe el sistema de telemando en la distribución de fuerza adoptado por la Comisión Británica de Trasporte para su programa de electrificación ferroviaria con corriente alterna. Con este sistema, un puesto de mando comprendiendo 600 ó 700 conmutadores y los otros aparatos necesarios para la distribución de fuerza, podrá gobernar hasta 600 miles de vía única, hallándose el puesto más lejano 70 miles del puesto de mando.

El artículo especifica las facilidades en los puestos de mando y hace observar que a pesar de que los pedidos para el aparato de mando han sido encargados a dos contratistas – la Automatic Telephone and Electric Company y Standard Telephones and Cables Ltd – está construído de tal manera que el operador puede actuar con la misma facilidad el aparato construído por el uno o por el otro de los contratistas.

Se describen e ilustran los métodos de señalización por frecuencia vocal entre el puesto de mando y los que este gobierna, métodos adoptados por los dos contratistas, así como los métodos de medida a distancia de la tensión de consumo y máxima demanda.

Se describen también el sistema de supervisión por hilo piloto y las disposiciones para su seguridad, así como los adoptados para reducir a lo más mínimo las consecuencias de una pérdida de línea.

Finalmente, los autores hacen mención del sistema telefónico destinado a emplearse con el sistema de mando, y de las facilidades para efectuar pruebas durante mantenimiento.

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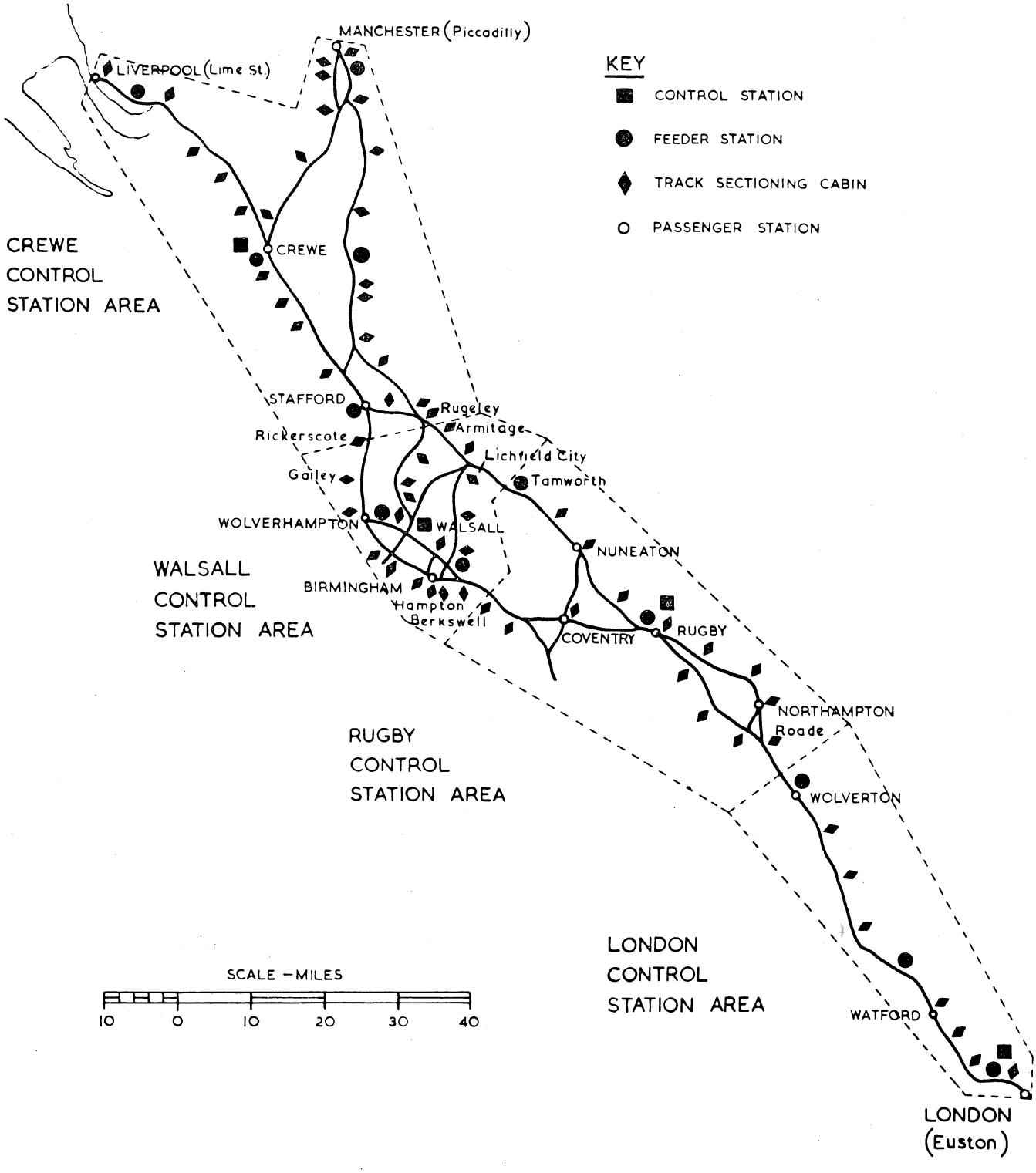

Fig.1 Authorised control areas, London Midland Region

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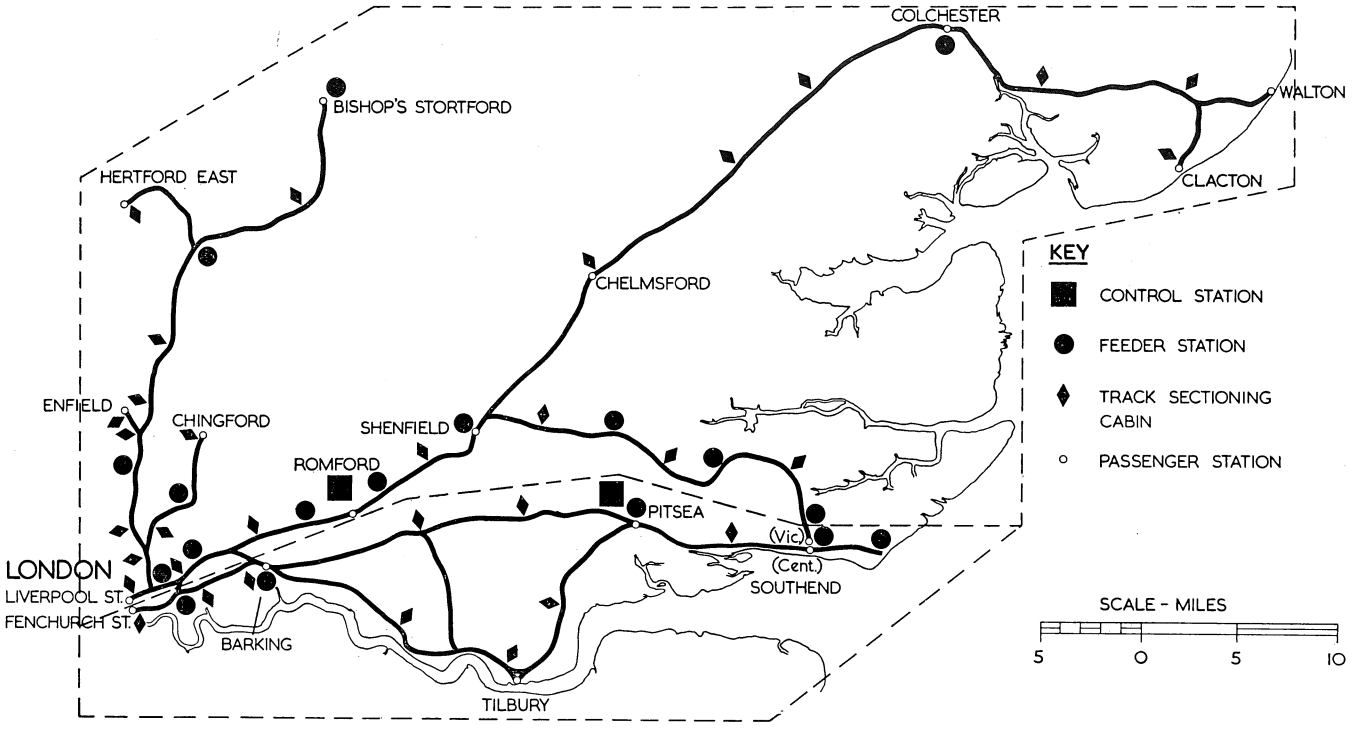

Fig.2 Authorised control areas: Eastern Region

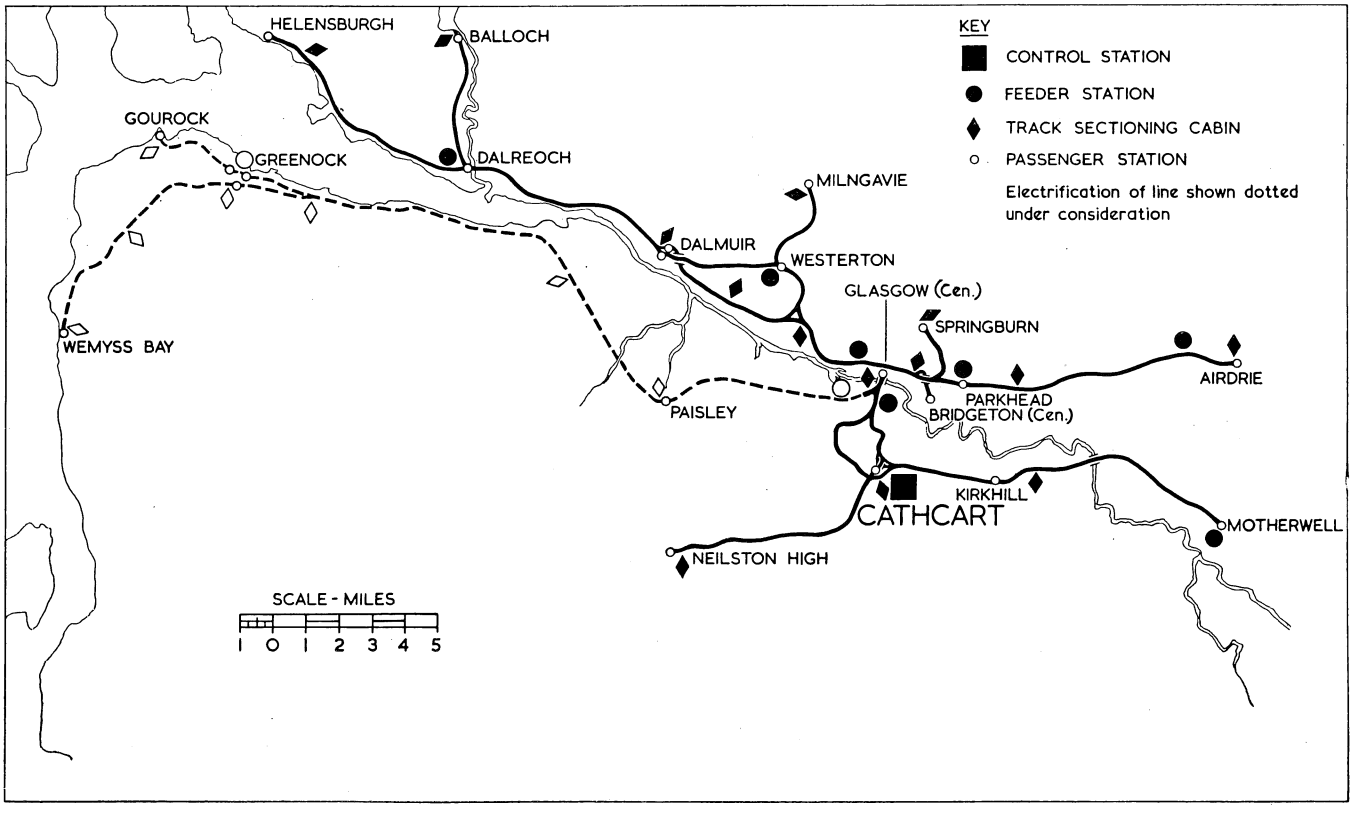

Fig.3 Cathcart control area: Scottish Region

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Fig.4 Crewe control room—Scenic diagram

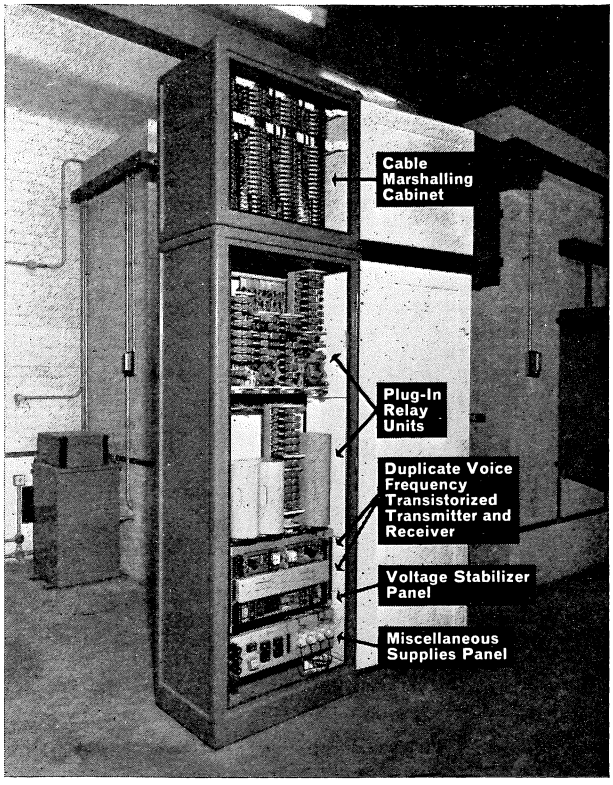

Fig.5 Typical supervisory equipment cubicle at a controlled station

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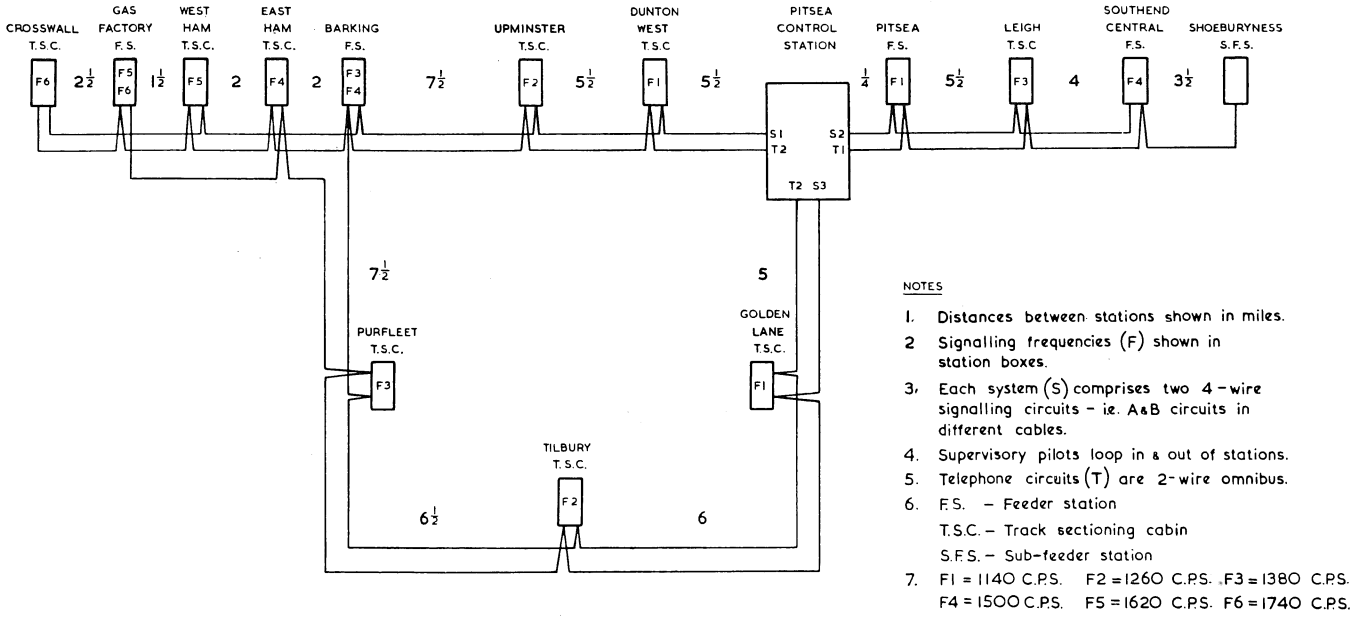

Fig.6 Utilisation of pilot wires and voice frequencies for supervisory system—Pitsea control area

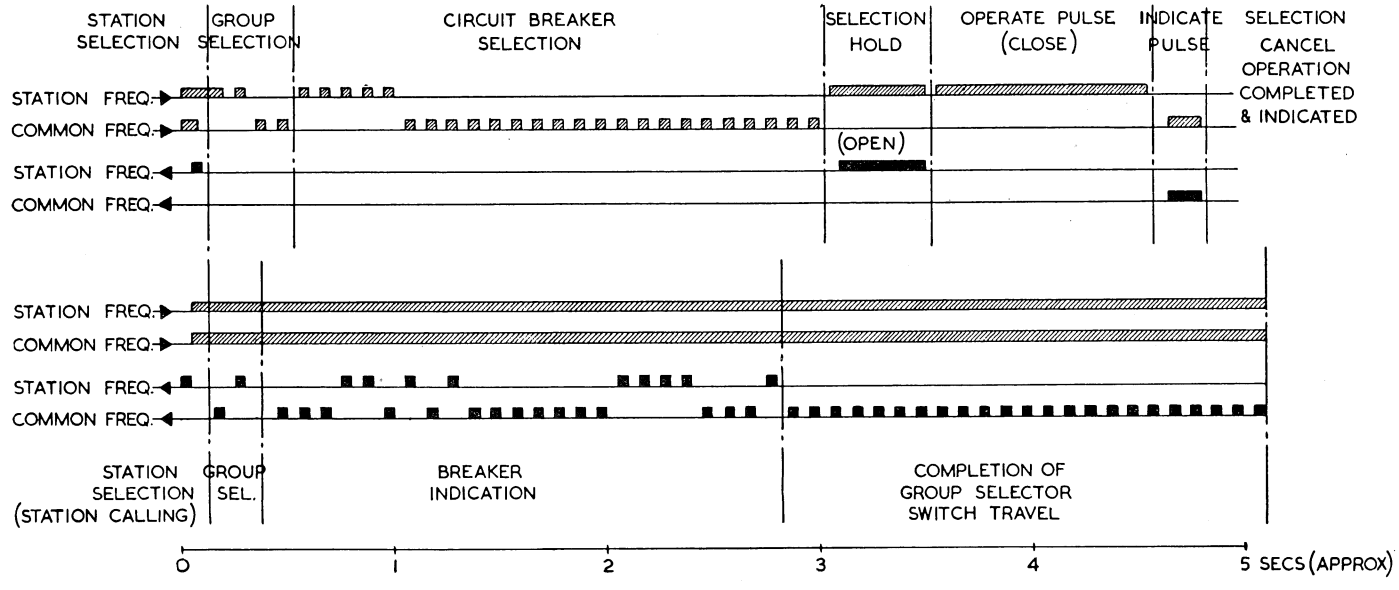

Fig.7 Line impulsing with two frequencies

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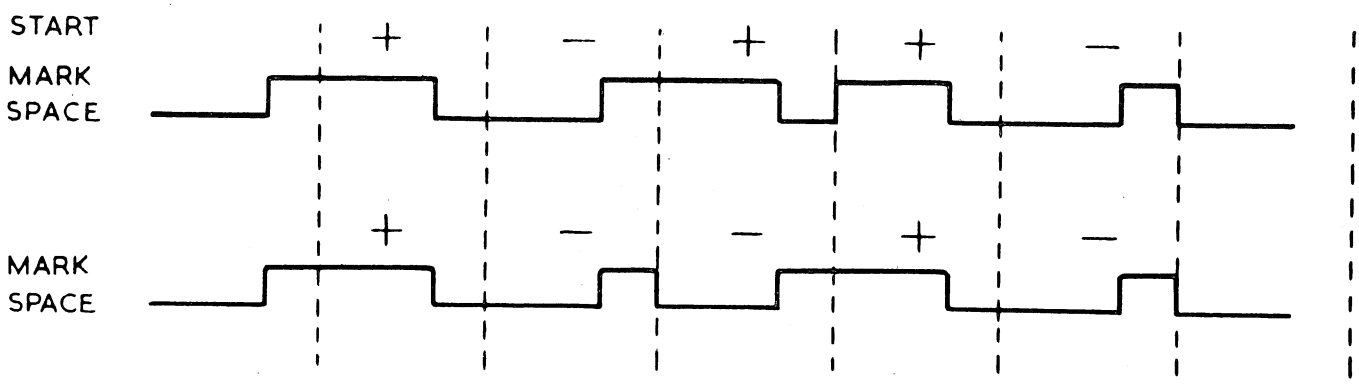

Fig.8 Typical impulse trains—Line impulsing using one frequency

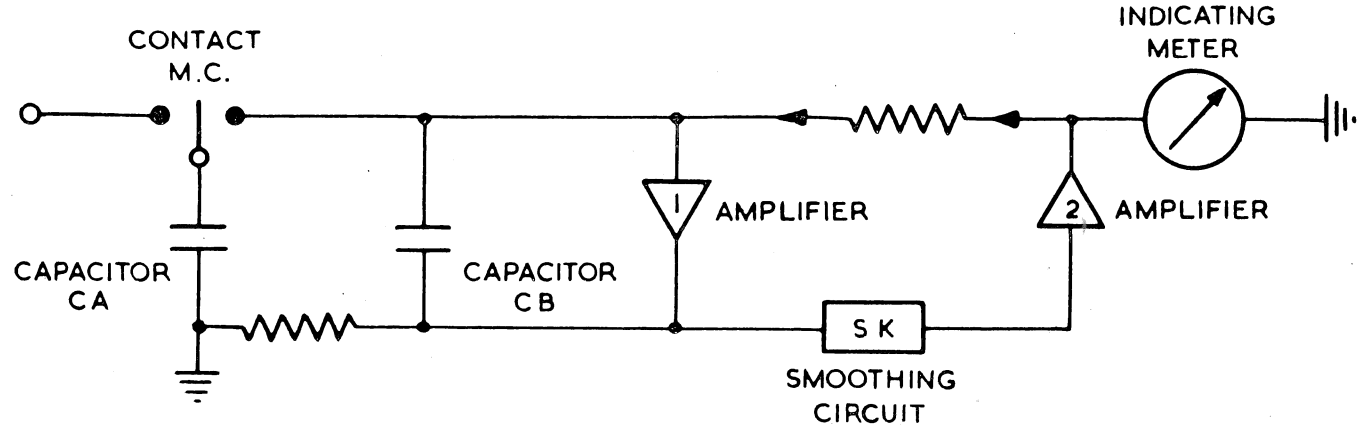

Fig.9 Impulse frequency telemeter basic circuit for voltage metering

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