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Paper 10

Signalling and Telecommunications

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1 Signalling and Telecommunications

1.1 *Introduction*

The proposals for the modernisation of British Railways necessitated consideration of a number of items of specific interest to the Signal Engineer. The main ones were, briefly, the decisions to change from steam motive power to electric or diesel power. Certain main and suburban lines were to be electrified on the 25 kV 50 cs. A.C. system and the Southern Region should have extensions of its existing D.C. system, the remaining main lines and services to be operated with diesel power – electric, hydraulic or mechanical transmission being used as appropriate.

It was further decided that the existing 1,500 V. D.C. overhead systems north of the river Thames should be converted to the A.C. 50 cs. system, normally at 25 kV, but using 6·25 kV where the structural clearance problem will be too costly to alter for 25 kV working.

On electrified lines general overall speed increases coupled with the anticipated increased traffic density, necessitate resignalling throughout in order to obtain adequate braking distances, together with the headways of from two to five minutes required by the new services.

1.2 *The Problems to be Solved*

The two major problems in which the Railway S. & T. Engineers are involved are:—

(*a*) Consideration of the conditions to be fulfilled in the transmission of both traction and track circuit currents in the rails.

(*b*) Interference with communication circuits. The magnitude of the interference problem obviously brings to the fore the effect on the national system operated by the G.P.O. as well as the effect on the railway signalling and telecommunication circuits.

Experience with early A.C. traction systems overseas and particularly with the old L.B.S.C. 6,600 V A.C. 25 cs. overhead system indicated that the extent of electrical interference with signalling and communication circuits was likely to be very severe. When the latter system was first introduced most communication circuits, both telegraph and telephone, were carried on open wire route, many in close proximity and parallel to the railway system. This was particularly so in the built-up areas. In spite of the remedial measures of using two conductors paralleling the rails, one being bonded to the rails at intervals and the other bonded to the first conductor at a few points only, (the whole idea being to give a better path than earth for the return circuit), interference with communication lines was not eliminated. The G.P.O. had to resort to cabling and diversion of these routes from close proximity to the railway. Even then all troubles were not eliminated, this installation being finally abandoned on the grouping of railways in 1922, when the Southern Railway (of which the L.B.S.C. Railway was a part), adopted the system in use on the other constituent company, the L.S.W. Railway, namely 660 V D.C. third rail top contact. From then onwards the telecommunication problem became one of earthing and unbalanced circuits.

The experience of this system was confirmed from various other countries where A.C. electrification was adopted. The new 50 cs. system therefore necessitated an intensive study being made of the interference problem so far as railways were concerned. It was fortunate that in the past 50 years a considerable body of information both theoretical and practical, has been built up and in addition, other factors, in particular economic ones, enable a reasonable solution of the problem of interference to be made.

So far as the third rail D.C. and the 1,500 V D.C. overhead railways are concerned the main problem is that of the track

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circuits. There is little inductive interference with communication circuits unless surges develop under fault conditions or during switching, given the condition in that the lines are not earthy or unbalanced and are in metallic sheathed cables.

2. Signalling with 50 cs. Traction

2.1 *Joint Use of Rails by Signal Engineers and Traction Engineers*

The rails, being conductive and in contact with the wheels, form a means whereby electric current can flow to or from a vehicle from any point on the track. From the very first, traction systems have made use of this ready-made means of obtaining a return path for the current. Almost concurrently with the first use of the rails as a conductor for traction current, the Signal Engineer was developing the track circuit as a means of detecting the presence of a vehicle within defined points on the track. But whereas the traction engineer wanted the rails to perform as a single solid undirectional conductor, the signal engineer made use of the fact that the wooden sleeper provided a sufficient degree of insulation for him to use the rails in a flow and return circuit in which the axles of a vehicle performed the switching function. Also the signal engineer desired, for both operating and technical reasons to cut the rails up into sections of varying lengths by the insertion of insulated fishplates. Thus engineers were faced with the need to find the most effective means of providing for two fundamentally different types of electric circuit in the same piece of metal.

2.2 *Methods Adopted with Present Traction Systems*

With a few exceptions the earlier traction systems used direct current and, after rather unsatisfactory efforts with polarized D.C. track circuits, the alternating current track circuit which employed an induction vane type of relay, completely immune to operation by D.C., became the established system of track circuiting in traction areas. At first, single rail track circuits were used; one rail was used jointly for track circuit and traction purposes and the other divided up with insulated joints to form the second pole of the track circuit. This arrangement, however, deprived the traction engineer of 50 per cent of the cross section of the return path otherwise available and with the ever increasing loads this became a serious handicap. The answer was the impedance bond which restored the full cross section of rail to the traction current while still providing conditions acceptable to the signal engineer. Naturally, for the alternating current track circuit the signal engineers generally used the standard commercial frequency of 50 cs. and apart from some concern at the high cost of impedance bonds a mutually satisfactory system resulted.

2.3 *Methods Adopted at Present and Results*

When the decision was made in 1956 to adopt A.C. traction at 50 cs. for all future electrification schemes on British Railways, a reconsideration of track circuit practices was necessary. Obviously the well established 50 cs. A.C. system would have to be abandoned, but before deciding upon the alternatives, consideration had to be given to the different behaviour of A.C. traction current in rails as compared with the familiar D.C.

Basically, the traction system would be a high voltage one, and therefore very much smaller currents were to be expected. On the other hand at 50 cs. the impedance of the steel rail becomes appreciable and the longitudinal potential drop per unit length will be greater. Fig.1 shows the manner in which the traction current gives rise to the flow of A.C. in the relay coils.

The variables and incalculables involved make it impossible to derive a reliable formula to give a value for the probable maximum traction current likely to flow at a particular location and it was decided to use as a basis the maximum normal current from one train all flowing from it in one direction. It was considered that such a figure would cover any probable combination of train currents likely to be encountered on one section of the return rail.

The value of rail impedance was derived from interpolation of the figures given in Bulletin No.12 of the Research Division of the Massachusetts Institute of Technology (1916). This gave a value producing a voltage drop of 5 V per 100 yards at 250 amps. Tests on modified D.C. track circuits showed that safe and reliable operation could be maintained with at least 50 V A.C. potential across the relay and on this a provisional maximum length of 500 yards for such track circuits was established.

2.4 *Alternative Methods Available*

In considering the use of D.C. track circuits in A.C. traction territory the amount of A.C. which could be tolerated by the relay had to be ascertained and steps taken to evolve a modified relay design to raise this level. The supporting Papers describe in detail how this immunisation is achieved.

To give further protection high impedance chokes having D.C. resistance of 14 ohms and A.C. impedance at 50 cs. of 785 ohms were inserted in series with the relay, and a typical track circuit of this type is shown in fig.2.

It was apparent that at the feed end of the orthodox rectifier fed D.C. track circuit, the A.C. potential across the rails would give rise to a half-wave rectified and effectively D.C. current which might have an adverse effect on the track circuit operation. To combat this, one firm produced an ingenious feed equipment which incorporated a testing rectifier which, when the D.C. component exceeded a predetermined value, operated a relay and disconnected the feed entirely. The elements of this system are shown in fig.3.

Experience to date, however, indicates that this risk is not serious and the insertion of a further reactance in the feed end of the track circuit has given adequate protection. The react-

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ance employed is carefully designed to eliminate any possibility of loss of impedance due to short circuited turns, etc.

The fact that D.C. track circuits are essentially of the single rail type and therefore limited in length to 500 yards encouraged consideration of track circuits which would permit the use of impedance bonds which, by balancing the traction return current, would considerably increase the permissible length of track circuit. The generation and distribution of A.C. at a different frequency would be a costly and cumbersome solution and the most attractive proposal was that of a track circuit using its own individual frequency generator (tied to the basic 50 cs.) at the feed end with an accurate and fail-safe frequency discriminator in the circuit at the relay end. This system produced a 75 cs. output when fed at standard 50 cs. and at the relay end the output from the discriminator was rectified and fed to an orthodox D.C. relay. This equipment has proved to be fully effective in operation, but suffers from the deficiency that its phase relationship with other similar equipments is arbitrary and this fact makes it inadvisable to employ them on adjacent sections. Such a limitation may not be onerous when alternate long and short track circuits are required, as would arise in a series of automatic signals giving a berth-overlap-berth sequence. Whilst the use of such equipment means that track circuits up to 1,500 yards may be permitted, the cost of the apparatus and the necessary impedance bonds is considerably more than that of the much simpler D.C. track circuit. In addition, it becomes necessary to impose limitations on its permissible extent of cross bonding for traction purposes and also takes away from the traction engineer the means of direct earthing of the overhead structures. If, as a result of this, a separate earthing wire has to be run through the section, any remaining saving obtained by using the longer track circuit is nullified and one leans to the opinion that the simple choke protected single rail D.C. track circuit, sub-divided into 500 yard sections, is probably the most economic system known at present.

A further factor which has influenced the preference for single rail D.C. track circuits is that, on average, track circuits in this country tend to be shorter than those employed abroad. This is due to closer spacing of the signals as a result of the high traffic intensity and to the use of separate overlap T.C.'s. A broad approximation is that two simple single rail track circuits are cheaper than one double rail equipment (including impedance bonds) but that on a 3 to 1 proportion the difference between the two types is marginal. Thus, if the average track circuit length is less than about 1,200 yards the economics favour the use of the D.C. equipment. Since the maximum advisable length even of a double rail track circuit is about 1,500 yards, i.e. three times the length of a single rail D.C. track circuit, there seems to be little prospect of the former type of equipment producing considerable financial advantage.

Trials have been made with more technically advanced track circuits and these include the audio-frequency pulsed type employing thermionic valves for generating frequencies of 350 and 800 cs. and used with appropriate impedance bonds as double rail track circuits up to 1,500 yards in length. A further type is the high voltage D.C. pulsed type employing a thyraton tube to produce a high voltage short duration pulse and using the impedance bond as a step-down transformer. The rail voltage employed is about 120, but the pulse duration is so short that power consumption is not excessive. Apart from the virtue of the latter type of equipment in breaking down insulating film on the rails, it has not so far been found that these types have any technical or financial advantage over the D.C. type. In general, in electrified areas in this country the intensive traffic ensures that rail film is not a serious problem.

2.5 *Special Case of Conversion*

As was stated earlier, the advent of 50 cs. A.C. traction called for re-thinking in respect of track circuit techniques and still further consideration was called for to deal with those installations originally electrified at 1,500 V D.C. and now to be converted to the new system. As was usual these sections were equipped with both single and double rail track circuits fed with 50 cs. A.C. and employing two-element vane type relays. The lines concerned were those from Liverpool Street to Southend and Chelmsford, comprising some 180 single track miles of continuous track circuiting with over 1,000 individual sections. Clearly D.C. track circuits were out of the question since this would mean the overnight changeover of all the equipment. A similar problem is found at Manchester and Euston on the London Midland Region and again will occur at other parts of the Eastern and North Eastern Regions when these lines are electrified. It was necessary, therefore, to devise a compatible system that could be progressively changed over under the D.C. traction conditions. The majority of the track relays were of modern design, either plug-in or detachable top, and clearly a great deal of work could be saved in re-wiring if the same basic units could be employed retaining the present plug-boards and tops. With this in mind it was decided to convert these track circuits to operate on a $83\frac{1}{3}$ cs. supply, protection against false operation by the 50 cs. traction current being obtained firstly by frequency selection in the track winding circuit of the relay and secondly by feeding the local winding from a second phase entirely independent from the one feeding the rails and protected against induced 50 cs. currents. The same feeders can also be used to supply line relay circuits previously operating at 50 cs.

Tests made at Fenchurch Street in 1957, when the overhead D.C. traction wires were temporarily converted to A.C. feed, indicated that the D.C. type impedance bond was quite suitable for use with an A.C. traction system and with an A.C. signalling supply at $83\frac{1}{3}$ cs.

The adoption of this system means that an entirely new power distribution system had to be superimposed on the existing one, and specially designed rotary converters were

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installed at the main power supply points. Duplicate machines with accurate monitoring and automatic changeover equipment were installed. The present 50 cs. distribution was retained to feed signal lighting and rectifiers for D.C. services. As soon as the new network and the converters were in operation a changeover programme was put in hand, using a float of additional track relays so that the existing ones could be withdrawn and rewound before being replaced into service at the new frequency. Recalibration of each track circuit is, of course, necessary. It was realised that should a fault occur in an impedance bond track connection at 50 cs. A.C. potential might build up on the track winding and be stepped up on the secondary winding of the auto bond to a dangerous level and that this voltage would stand on open terminals in the location cases. Consequently all impedance bonds are being converted to resonated type with the resonating condensers housed in separate sealed units which, once the bond had been calibrated, need not be opened for normal maintenance purposes. Fig.4 shows a typical double rail A.C. track circuit as modified to operate on $83\frac{1}{3}$ cs.

The requirements of the G.P.O. necessitated in certain areas the introduction of booster transformers in the traction return system to more effectively reduced interference. On the Manchester – Crewe line where no return conductor was provided, it was found necessary to introduce a short track circuit about 120 ft. long at booster transformer, in the manner shown in fig.5, to reduce the potential across the insulated rail joints. A voltage of about 200 V has been measured across a rail joint near such a transformer before the short track circuit was introduced.

It is general practice on British Railways to use No.8 gauge copper wire for track circuit bonding, two of these bonds being used at each rail joint. It was found that, as a result of tests, the traction return current could be carried by an ordinary track circuit double wire bond. One wire, however, would overheat if it had to carry the whole of the traction return current and it was decided that three such wire bonds would be adequate for all purposes. The decision was therefore made that in double rail track circuited areas only two bond wires should be used per joint, as the traction current is split between the two rails; in single rail track circuited areas the traction return rail should have three of these bond wires per joint and the track circuit rail two bond wires per joint. This serves as an easy method for identification purposes in that no earth connections from structures, etc., are to be made to rails with only two bond wires per joint. The three bond wires identify the return rail. The signal engineer maintains these bonds and this is somewhat of an innovation in this country.

2.6 *Power Supplies*

Power supplies for signalling purposes must be derived from two substantially independent sources. Except at the large and important centres where a prime-mover standby set is generally considered to be a justifiable investment, power is taken from a local source, usually in the vicinity of a track feeder or track sectioning cabin, and the standby is obtained from the overhead lines. Details of the equipment for providing the standby supplies are given in Paper 5. High speed automatic changeover contactors are employed with appropriate monitoring equipment.

3. Telecommunications

3.1 *The Interference Problem*

For over 25 years the C.C.I.F. and C.C.I.T. (now amalgamated as the C.C.I.T.T.) have studied the interference problem from the point of view of the public system of telephone and telegraph networks and certain guiding principles recommending standards beyond which interference from either overhead lines or railway electric systems shall not go. Generally speaking the conditions existing between the public communication system and the railway system are such that they cannot be so onerous as those to be expected by railway communication and signalling circuits, which parallel the electric railway throughout its length at very close proximity. The conditions for railway circuits have to be considered both from the point of view of induced interference and also whether conditions can arise causing failures of apparatus and danger to men working on the circuits.

It was therefore decided that the 'Directives' of the C.C.I.F. and C.C.I.T. should apply as far as possible to railway lineside circuits, the relevant recommendations being as follows:—

1. During the normal functioning of the power line, or electric traction system, the longitudinally induced voltage in telecommunications circuits should not exceed 60 V (unless condition 3 applies).
2. Under fault conditions of power line or electric traction system, the longitudinally induced voltage in telecommunication circuits should not exceed 430 V (unless condition 3 applies).
3. In the case of cable circuits which are not fitted with lightning protectors and which are terminated on adequately insulated transformers, the limiting induced voltage may be taken as 60 per cent of the test voltage of the cable between conductors and sheath, or 60 per cent of the test voltage of the cable accessories.
4. The noise limit for a telephone circuit is expressed in terms of psophometric e.m.f. which should not exceed 2m.V.

The 'Directives' do not cater for interference to the signalling functions of telephone circuits, it being assumed that the circuits are sufficiently well balanced to avoid such difficulties, provided that the above conditions are met. Consequently it is essential that the railway's telephone circuits in electrified areas shall employ well balanced terminations.

It will be seen how far these conditions are complied with, firstly from the preliminary tests made recently and finally when the Systems Tests are completed.

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3.2 *The Telecommunication Circuits*

The induction effects of the overhead traction system are, of course, extremely important and it was the first problem to be given great attention.

It was obvious from previous experience that the railway overhead lines would have to be cabled, owing to their close proximity to the catenary system. Next, the public system of telecommunications owned by the G.P.O. had to be protected against the effects of the traction system, and details of the measures adopted to safeguard these circuits will be found in Papers 9 and 37.

Taking the railway signalling and telecommunication circuits first, many of them from past practice have either earth returns or possibly are D.C. circuits, two wire, with a centre earth connection, and make use of polarised lines. With electric traction this type of circuit becomes impossible. In view of the fact that at present the electrification is on main lines and lines with intense suburban services, the new colour light signalling has eliminated this type of circuit both from the signalling and associated telephone circuits, the block telegraph system being replaced by train describers and continuous track circuiting. The variety of circuits for which provision has had to be made and the means adopted in one particular installation are indicated in Table 1 attached to this Paper.

3.3 *Signalling Circuits*

It was decided that, since there was no exposure of other than technical staff to any direct contact with line circuits, the limitation of the 60 V in the C.C.I.T.T. 'Directive' could be raised to 110 V. This is a value already commonly in use on A.C. signalling systems. The maximum value of 430 V under fault conditions was retained for signalling circuits. Since the average length of exposure of inductive effects of signalling circuits is not great it was decided that no attempt would be made to provide screening in the cables. Unusually long circuits are relayed at intervals the maximum length being determined by the designed short circuit traction current limits of the section concerned. Lengths of between three and five miles appear to be the general case.

If and when the electrification is extended to subsidiary and single lines with sparse traffic, some further consideration of the problem will have to be made, not so much on the technical side as on the economic side. Single line signalling systems using electric train tokens will undoubtedly not be very practicable under these circumstances.

British Railways are therefore faced with cabling the whole of the signalling and telecommunication cables in such a form as to reduce the effects of interference from the new traction system. If any other form of motive power unit had been adopted, the re-designing of the signalling and telecommunication systems would in most cases have necessitated cabling owing to the increase in the number of conductors required. It is therefore only the provision of adequate cable screening and immunisation of the apparatus which becomes an additional cost to the electrification scheme. It is the cost of this screening which influences any steps taken on the traction system to minimise interference.

The problem of interference is therefore reduced to one of economies involving:—

(*a*) Immunisation of the railway cable system and/or

(*b*) Reduction at source of the interference.

The theory of interference and the techniques adopted to combat the effects are fully dealt with in Papers 9 and 41.

4. Preliminary Tests to Prove the Safety of Circuits

4.1 *Description of Tests*

Tests by the Signal Engineer have so far been in two stages. The first series were carried out on the Lancaster – Morecombe line of the Midland Region and at Fenchurch Street and Shenfield on the Eastern Region when existing overhead lines were energised at 50 cs. A.C. In the case of the Eastern Region, lines normally working at 1,500 V D.C. were temporarily changed over for a few hours only. On the basis of the results from these tests, which were of necessity very limited in their scope, specifications for the equipment on the new lines were drawn up. The second series of tests were those carried out on the Slade Lane – Wilmslow (Styal) line and the Colchester – Clacton line immediately before the new 50 cs. electrification schemes were put into service and continued after electric services were running. The latter series of tests had the purpose of proving that no unsafe conditions would arise in the operation of the line and also of showing where any forecasts made on the basis of the earlier and incomplete tests required reconsideration.

4.2 *Tests on Track Circuits*

Tests with various values of rail current up to 500 amps. showed that the calculated figure of 5 V per 100 yards for 250 amps. was correct and that even with 100 V across the rails the choke protected D.C. track circuits continued to work satisfactorily. When the pattern of traction return currents has been established by the Systems Tests it may well be found that lengths of over 500 yards can be tolerated for single rail track circuits.

Under short circuit fault conditions rail to rail voltages of up to 300 V were measured, but no interference with track circuit operation was experienced.

On the double rail track circuits the tests showed that a maximum of 4 V out of balance may be expected and this is below the value of 5 V at which saturation of the relay and transformer may cause a right side failure of the circuit.

4.3 *Induced Voltages in Signalling Cables*

Induced voltages measured in the unscreened signalling cables under both normal and short circuit conditions con-

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firmed the results of earlier trials at Fenchurch St. and Shenfield when a figure of 50mV per ampere mile was derived as being a reasonable basis on which to calculate the maximum continuous exposure that was desirable. It was found that the limit was reached under fault conditions and if the cable lengths were limited to suit these, there was ample margin under normal maximum load conditions.

On the Colchester – Clacton section the tests resulted in setting a maximum length of circuit at 2·9 miles on the London side of Alresford and 4·7 miles on the Clacton side.

On the Styal line similar values were experienced, but the installation was installed in the first place with circuits limited to 1,400 yards. This now appears to have been a little over-cautious.

4.4 *Induced Voltages in Telecommunications Cables*

On the Styal line which is equipped with booster transformers but with no return conductors, the cables have four steel tapes for inductive protection. The tests show that values of induced voltage under both normal maximum and short circuit current conditions were well within the stipulated limits of 60 V and 430 V respectively.

On the Clacton line, where return conductors and booster transformers are installed, the cable has only an aluminium sheath. The highest figure under maximum load conditions was 5mV per ampere mile which means that an exposure to 600 amps. for 20 miles could be tolerated. Under short circuit conditions, a highest level of 31mV/ampere mile was measured with an exposure of nine miles to a fault current of 1,400 amps. It is clear from these tests that the fault current produces the most onerous conditions and on the Clacton line a repeater station was installed at Wivenhoe, four miles from Colchester, where the traction feeder is located. This has ensured that the induced voltage will not exceed 430 V even on the longest circuits ($17\frac{1}{2}$ miles).

Noise tests on both systems showed that no unacceptable level was reached under any condition.

4.5 *The System Tests*

The proving tests mentioned are obviously very sketchy and were only carried out as stated to enable certain preliminary checks to be made. The full system tests to be undertaken will take account of the following requirements of signal and telecommunication engineers:—

1. Measurement of induced voltage in circuits of various lengths of screened and 'unscreened' cables.
2. Measurement of psophometric e.m.f. in telephone cables.
3. Measurement of rail to rail and rail to earth voltages.
4. Harmonic analysis of the above rail voltage measurements.
5. Measurement of rail current distribution in a typical section.
6. Measurement of traction current to enable the associated traction conditions to be ascertained in the case of any desired induced voltage measurement.

4.6 *Conclusion*

The aim of both the signalling and telecommunication designers has been to solve the problems of the track circuit and interference in the simplest possible way rather than to develop intricate apparatus for the same purpose. The results to date indicate that under the conditions applicable in this country workable solutions have been found to most of the problems.

By the time the Conference is over, there will be confirmation that the signalling and telecommunication systems adopted for the Manchester – Crewe section are operationally effective and by the end of the year it is expected that similar conclusions will be evident in respect of the other electrified lines.

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TABLE 1

Circuits Carried by Railway Telecommunications Cables

Item No.	*Class of Circuit*	*Means of Provision*	*Examples (see Note B)*
1	Main trunk telephone and telegraph circuits	Carrier telephone circuits and multi-channel V.F. telegraph circuits	Partly 24 pair and partly 14 pair 36 lb. carrier cable. (Cable No.1)
2	Exchange tie lines	(*a*) Audio circuits with 17 c/s ringing	Four loaded pairs between Crewe and Ditton and between Ditton and Lime Street (in Cable No.2)
		(*b*) C.B. signalling or dialling	—
3	Direct telephone lines from Electric Control Room	(*a*) Audio circuits with 17 c/s ringing	From Crewe Electric Control Room, Four loaded pairs in Cable No.2 to Lime Street Exchange, C.E.A. etc.
		(*b*) C.B. signalling or dialling	—
4	Exchange extension lines	C.B. circuits requiring D.C. path	Pairs in Cable No.2 (long distance circuits to be loaded)
5	Code call control circuits	Audio circuits utilising coded D.C. ringing	Dial selective system (item 7) proposed
6	Existing selective control circuits, including dial types	Audio circuits utilising coded pulses for calling	Dial selective system (item 7) proposed
7	Newly developed dial selective control	Audio circuits using 50 c/s calling modulated by code pulses	Loaded pairs in Cable No.2 and unloaded pairs in Cable No.3
8	Omnibus circuits	Audio circuits using D.C. coded call	Suggested use of circuit type under item 9, but some difficulty feared in providing flexibility in ' conference ' facilities
9	Dial selective omnibus circuits	Audio circuits with D.C. loop dialling and revertive 50 c/s call (system still under development)	Loaded pairs in Cable No.2 (see item 8 above)
10	Main inter-traffic control circuits	Probably 50 c/s signalling (10 station dial selective system still under development)	Loaded pairs in Cable No.2 giving communication between a number of locations at Crewe and a number of locations at Liverpool. (In this case there are no intermediate stations)
11	Electrification telephone circuits	Probably as item 7	Loaded pairs in Cable No.2 connected to unloaded pairs of length, say, 15 miles, in Cable No.3
12	Signal post telephone circuits	C.B. selective telephone circuits. (A call from an outside 'phone locks out all other 'phones and brings in signal location identification lamp at the signal box	Unloaded pairs in Cable No.3 (one pair per running line in every direction)
13	Signal Engineer's maintenance telephone circuits	(*a*) Local battery telephones with magneto call (*b*) C.B. plug in circuit connected to trackside locations	Box to box circuits with up to six intermediate points Circuits extending to limits of each signal box control area. Two pairs in Cable No.3 in every direction
14	V.F. telegraph point to point circuits	V.F. telegraphy	Two loaded pairs in Cable No.2 to Ditton from Crewe and Liverpool
15	V.F. telegraph circuits for train reporting (with intermediate stations)	V.F. telegraphy	Two loaded pairs in Cable No.2
16	D.C. telegraph circuits	D.C.	Only circuits as in items 14 and 15 are proposed
17	Train describer (box to box) circuits	Coded D.C. pulses	One pair per running line in Cable No.3
18	Emergency block bell circuits	D.C.	One pair per running line in Cable No.2
19	Block telephones (box to box)	Local battery telephones with magneto or battery ringing	One pair per section in Cable No.2
20	Occupation Crossings	Local battery telephones with magneto ringing	—
21	Remote control system for phantom signal boxes	40 kc/s modulated carrier	Two pairs in Cable No.3 to each remote control location from parent signal box. (Carrier system adopted in Crewe – Manchester scheme. Other remote control systems employing D.C. or V.F. coding are available)
22	Ground frame bells	D.C. single stroke bells	One pair per ground frame in Cable No.3

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Item No.	*Class of Circuit*	*Means of Provision*	*Examples (see Note B)*
23	Ground frame telephone	C.B.	One pair per ground frame in Cable No.3
24	A and B Supervisory pilot circuits	V.F. supervisory equipment	Loaded pairs in Cables Nos.2 and 3
25	Supervisory satellite circuits (remote operation of isolating switches between T.S.C.s)	D.C. operation from nearest T.S.C.	Total of 10 to 22 pairs in Cables Nos. 2 and 3
26	Satellite maintenance telephone circuits	Magneto plug-in circuit from parent T.S.C.	One pair in Cable No.3
27	Loudspeaker circuits for staff location	Loudspeakers connected to twin cable which is divided into sections each of which is fed with coded V.F. tone from oscillators housed in relay rooms. Oscillator tone signalling is controlled by D.C. circuits	Two pairs in Cable No.3 for controlling circuits. Independent twin loudspeaker cable
28	Centralised Traffic Control Circuits	Probably coded pulses	—
29	'Desfax' circuits	Audio circuit with D.C. control over earth return	—
30	Television	Dependent on circumstances	—
31	Common time circuit for synchronising station electric clocks	50 c/s or D.C. impulsing (system still under development)	One master control pair in Cable No.2
32	Data processing circuits	Telegraph type of transmission, in some cases a wide bandwidth being necessary	—

Notes

(A) The above information is intended to give some idea as to the types of circuits which will require consideration in assessing the practicability of applying the principles outlined in paragraph 76 of the 'Directives of the C.C.I.F. and C.C.I.T.'.

(B) Column 4 has been included in order to illustrate the applications. The information relates to the Liverpool – Crew section. Three telecommunications cables will be laid:

Cable No.1: 36 lbs/mile carrier telephone cable
(partly 24 pair and partly 14 pair)

Cable No.2: 40 lbs/mile V.F. telephone cable
(partly 104 pair and partly 74 pair)

Cable No.3: 40 lbs/mile V.F. telephone cable
(54 pair)

(A fourth cable, 104 pair 40 lbs/mile, is laid between Edge Hill and Lime Street.)

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SUMMARY

This Paper, which is concerned with the effect of electrification on signalling and railway telecommunications, begins with a statement of the problem and refers to experience on earlier electrifications.

After describing the interests of both the Signal and the Electrical Engineer in the running rails, it discusses the various methods of track circuiting that have been used in the past and are being used on the present electrification schemes to ensure that the reliability of signalling is not affected by interference arising from the electric traction system. It deals in detail with the special case of having to convert equipment which was installed for the electrification of the Liverpool Street – Southend – Chelmsford line on the 1,500 volt D.C. system to make it suitable to work both on this system and on the 25 kV or 6·25 kV 50 cycle systems to which it is to be converted overnight.

The telecommunication section of the Paper begins with a statement of the permissible limits of disturbing voltage and shows the adherence of British Railways to the C.C.I.T.T. Directives.

General descriptions are given of the methods of immunising these circuits. Some particulars are given of tests that have already been made and reference is made to tests under the System Tests project.

RÉSUMÉ

Cet exposé qui a pour objet l'effet de l'électrification sur les lignes de signalisation et de télécommunications, commence par poser le problème et se rapporte à l'expérience des électrifications précédentes.

Après avoir rappelé l'intérêt de l'ingénieur de Signalisation et de l'ingénieur tractionnaire pour les files de rails, il discute les diverses méthodes de circuits de voie qui ont été utilisés dans le passé et qui sont en utilisation dans les électrifications actuelles pour assurer que la sécurité de signalisation ne soit pas affectée par les perturbations dues aux circuits de traction. Il traite en détail le cas spécial de la conversion de l'équipement installé pendant l'électrification de la ligne Liverpool Street – Chelmsford – Southend en courant continu 1500V pour rendre son utilisation possible aussi bien en courant continu 1500V qu'en 25 kV ou 6,25 kV à 50 Hz, système auquel la ligne sera changée en une nuit.

La partie sur les télécommunications donne d'abord les limites permises des tensions perturbatrices et souligne l'adhésion des Chemins de Fer Britanniques aux directives du C.C.I.T.T.

On donne une description générale des méthodes employées pour rendre les circuits de voie insensibles aux courants de traction. Quelques détails sont donnés des essais qui ont été déjà effectués, et on cite les essais prévus dans le cadre d'Essais de Système.

ZUSAMMENFASSUNG

Dieser Bericht, der sich mit dem Einfluss der Elektrifizierung auf das Signalsystem und Fernmeldewesen der Eisenbahnen befasst, beginnt mit der Feststellung des Problems und bezieht sich auf Erfahrungen früherer Elektrifikationen.

Nach der Erörterung der Interessen, die der Signal- und der Traktionsingeneur an den Fahrschienen haben, werden die verschiedenen Gleisstromkreis-Systeme, die in der Vergangenheit angewandt wurden und die in den heutigen Elektrifikationsplänen figurieren, diskutiert, um die Sicherheit zu haben, dass die Zuverlässigkeit des Signalsystems nicht beeinflusst wird durch Störung vom Bahnstromnetz. Der Bericht behandelt ausführlich den Spezialfall der Umänderung der 1,500V Gleichstrom-Ausrüstung, welche anlässlich der Elektrifikation der Linie Liverpool Street – Southend – Chelmsford installiert wurde, auf das 25 kV oder 6.25 kV, 50 Hz Wechselstromsystem. Die Ausrüstung soll über Nacht vom Gleichstrom- auf das Wechselstromsystem umgeändert werden.

Der Fernmeldeabschnitt des Berichtes beginnt mit der Feststellung der zulässigen Störspannungs-Höchstwerte und weist auf das Festhalten der 'British Railways' an den C.C.I.T.T.-Vorschriften hin.

Allgemeine Beschreibungen der Methoden, wie diese Stromkreise immunisiert werden, sind angegeben. Einige Einzelheiten von bisher gemachten Versuchen sind angeführt, ferner wird auf die Versuche in Verbindung mit dem System-Prüfprogramm hingewiesen.

RESÚMEN

Este documento, que se ocupa del efecto de la electrificación en la señalización y telecomunicaciones de los ferrocarriles, empieza definiendo el problema. Acto seguido pasa a relatar la experiencia cosechada en anteriores sistemas de electrificación.

Después de describir el nexo que existe entre los carriles de la vía y los Ingenieros Electricista y de Señales, aborda los diversos métodos de poner la vía en circuito que se han empleado en el pasado – y que se siguen usando en los actuales sistemas de electrificación – para conseguir que la confiabilidad de la señalización no se vea afectada por las interferencias producidas por el sistema eléctrico de tracción. Trata detallado del caso específico de tener que convertir el equipo que se instaló para la electrificación de la línea Liverpool Street – Southend – Chelmsford al sistema de corriente continua de 1,500 voltios, a fin de poder usar este equipo tanto en este sistema como en los sistemas de 50 ciclos, de 25 kV ó 6,25 kV, a los cuales se conmutará rápidamente.

La sección que versa sobre las telecomunicaciones empieza exponiendo los límites permitidos en el voltaje perturbador y pone de manifiesto el hecho de que los Ferrocarriles Británicos se atienen a las Recomendaciones de C.C.I.T.T.

Se hacen alusiones de carácter general a los métodos de inmunizar estos circuitos. Se facilitan, asimismo, algunos pormenores sobre las pruebas que ya se han realizado y se hace referencia a las pruebas amparadas por el proyecto de Ensayos de Sistemas.

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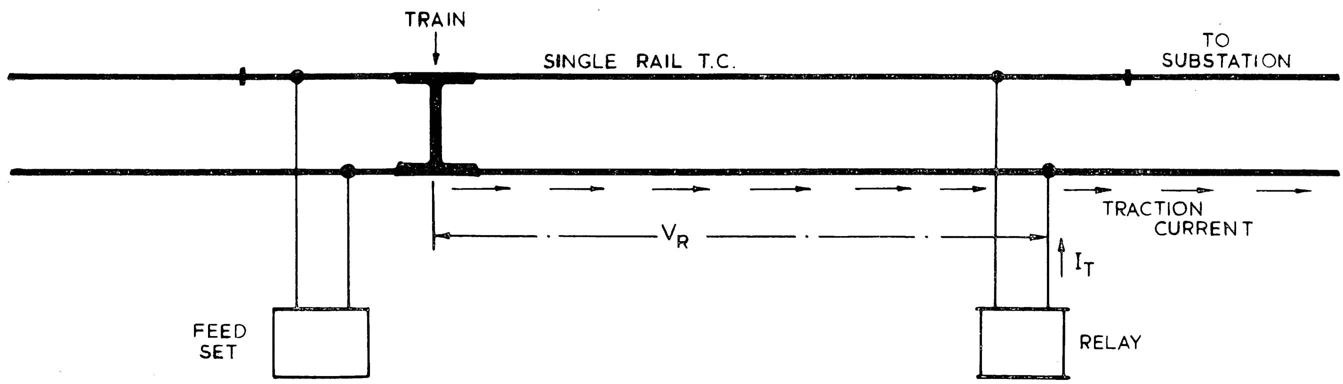

$$V_R = \text{RAIL IMPEDANCE} \times \text{TRACTION CURRENT}$$

$$I_T = \frac{V_R}{\text{RAIL IMPEDANCE} + \text{RELAY IMPEDANCE}}$$

$$\simeq \frac{V_R}{\text{RELAY IMPEDANCE}}$$

Fig.1 A.C. current flow in track relay due to voltage drop in rail

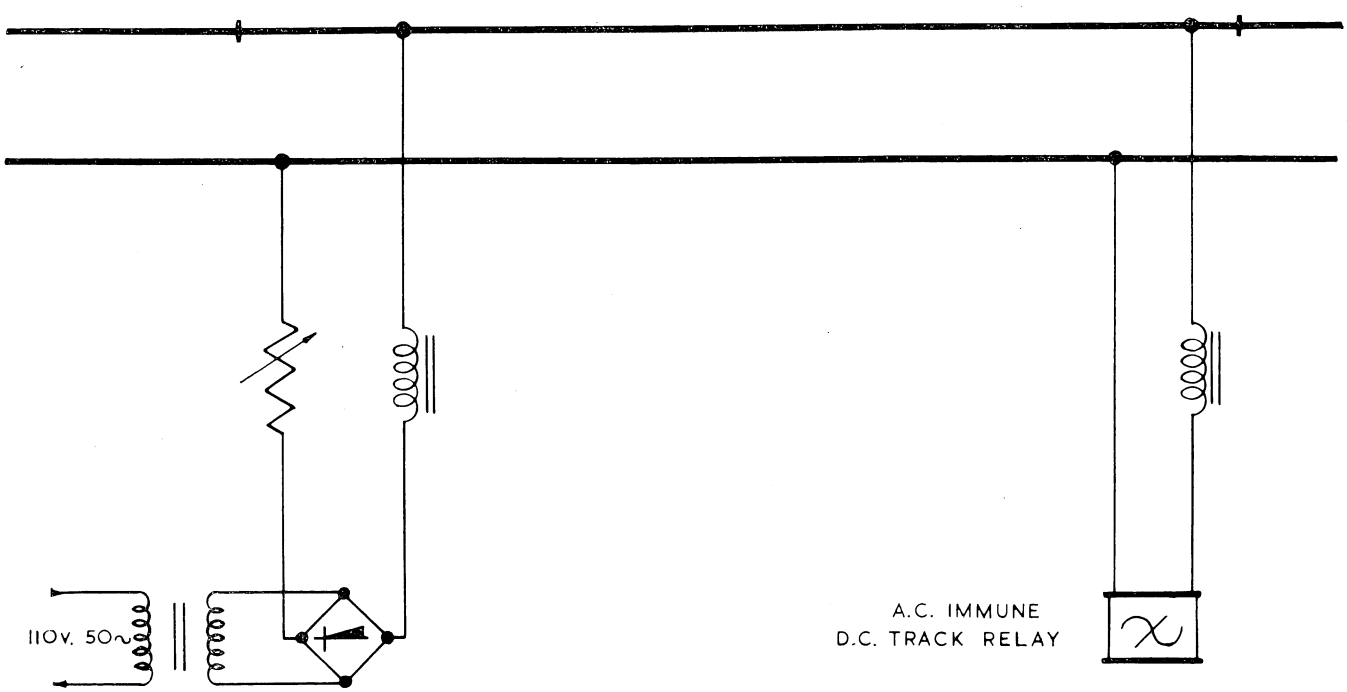

Fig.2 Choke protected D.C. track circuit

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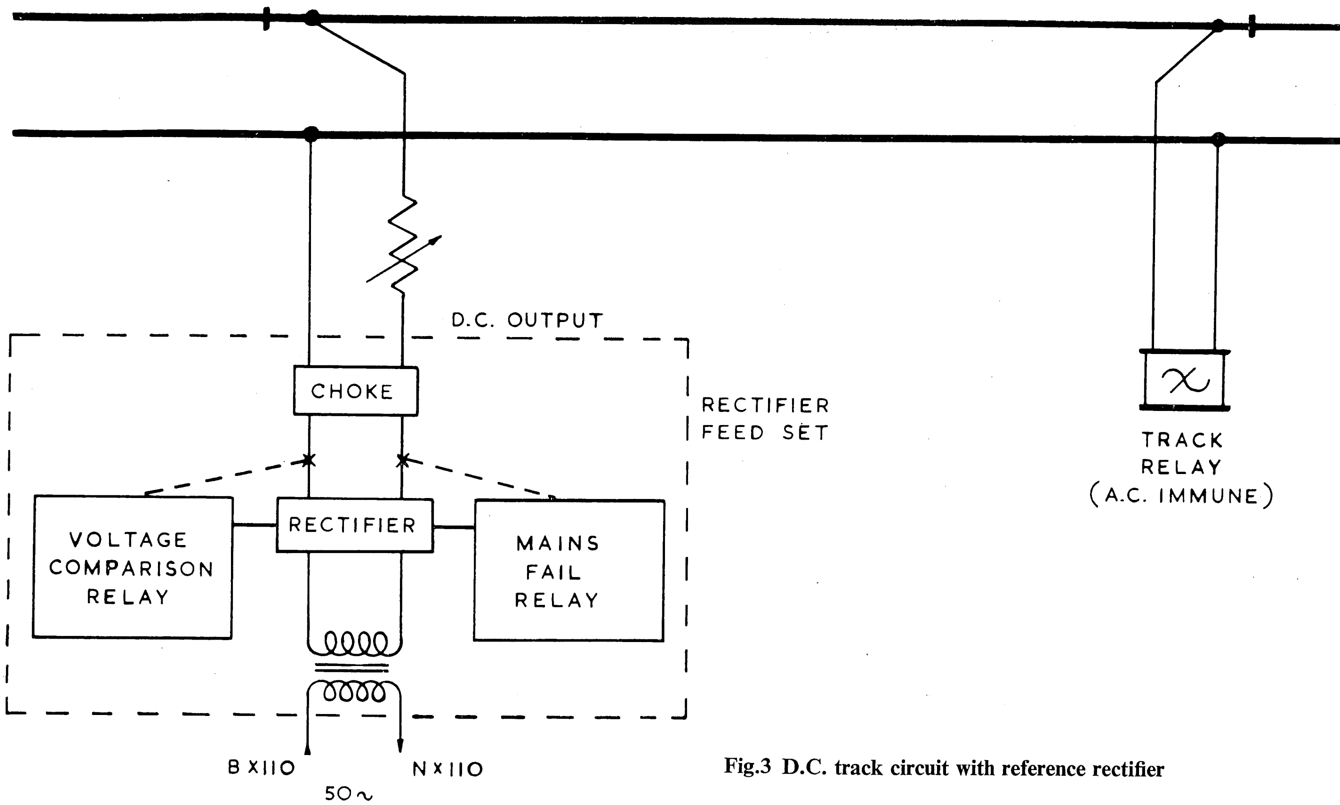

Fig.3 D.C. track circuit with reference rectifier

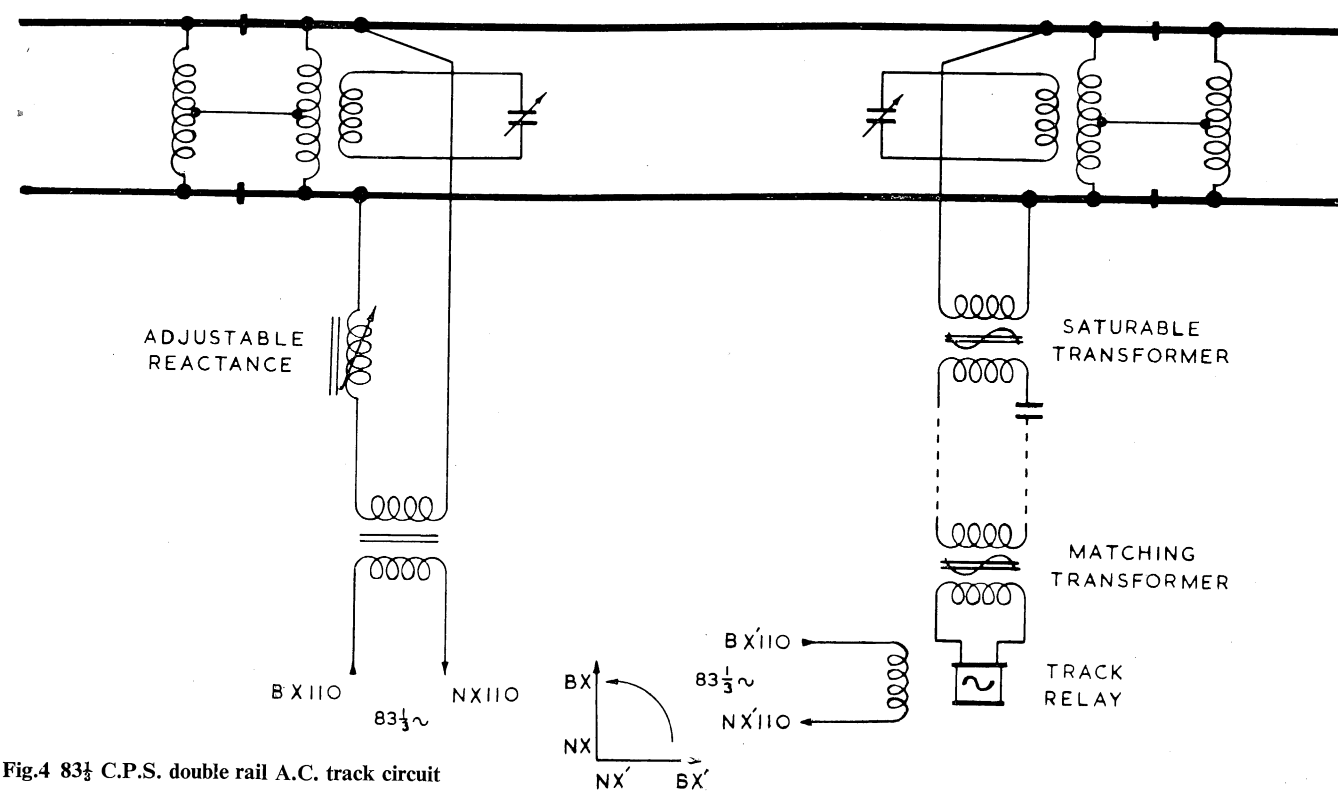

Fig.4 83⅓ C.P.S. double rail A.C. track circuit

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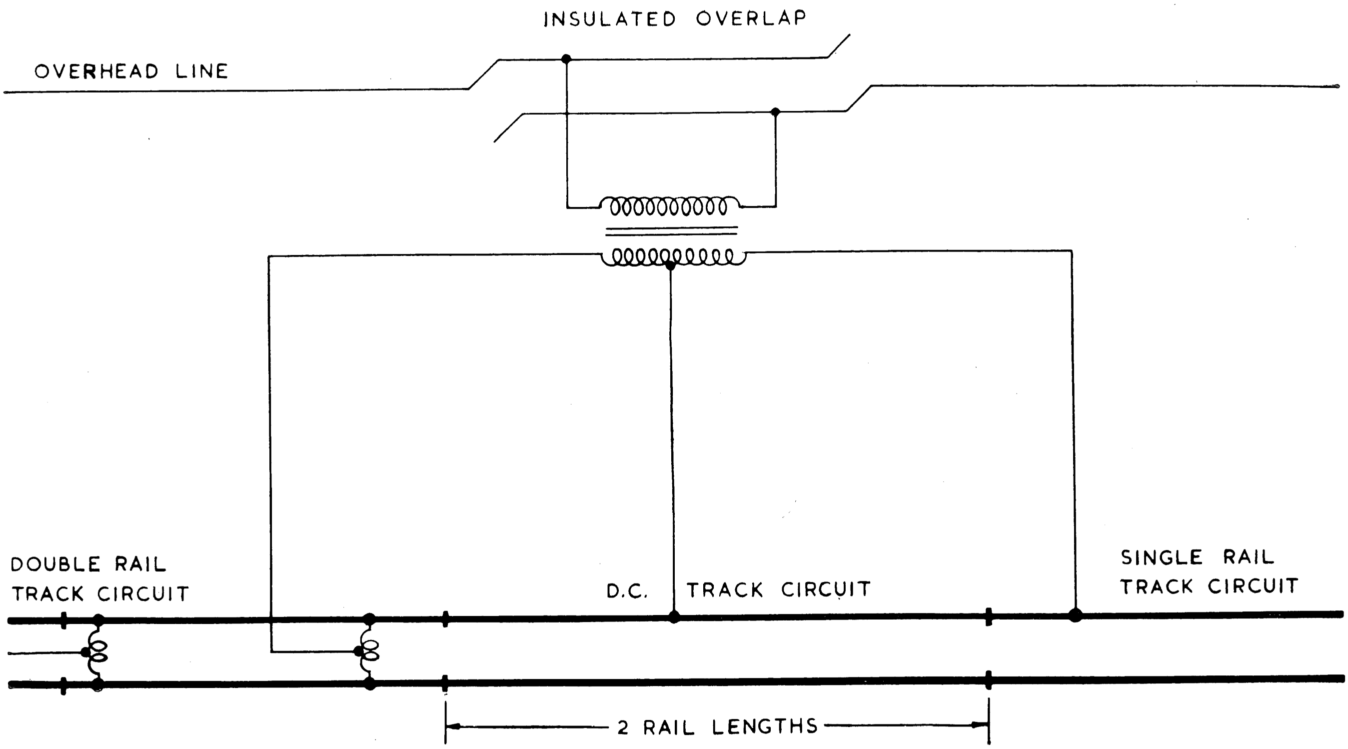

Fig.5 Potential dividing track circuit at booster transformer location

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