Signal Development in Connection With Single Phase Propulsion

The New York, New Haven & Hartford Develops A. C. Signaling to Meet Special Characteristics Caused by Electric Operation

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AT THE time that preliminary studies for the electrification of the New Haven between South Mount Vernon, N. Y., and Stamford, Conn., were made, very little, if any, consideration was given to the subject of railway signals, and not until the matter of power return was being developed did the subject come before the electrification engineers. At every interlocking tower all four tracks were divided into track circuit sections by insulated joints in the rails which interrupted the continuity of the negative or rail return.

To provide for the power return through the track circuit sections, a scheme was devised to use one rail of each track for the power return, retaining one rail insulated for the track circuit section. The existing primary battery was to be retained but the ordinary track relay was to be replaced with a slow releasing track relay connected in series with a reactor. The slow releasing track relay was according to standard signal engineering practice, except that a copper sleeve was placed over each of the magnet cores which retarded materially the de-energization of the magnet. The relay and the reactor in series had sufficient choking effect to 25 cycles current to require a drop in potential across the reactor and relay of from 72 to 75 volts before the relay would chatter.

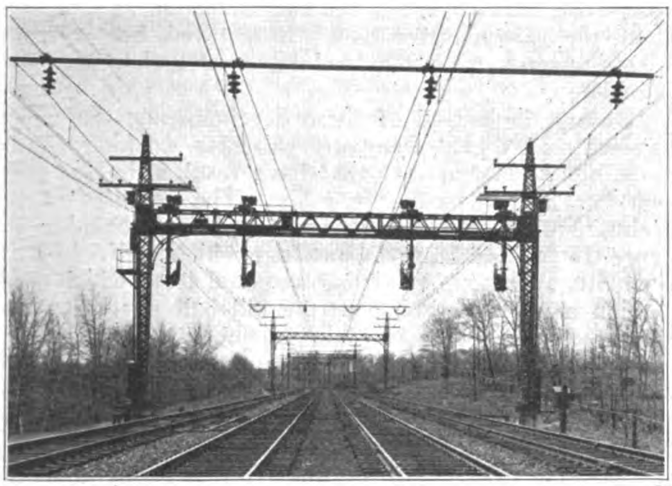

Fig. 1—Typical Automatic Signal. Note the Duplicate Transformer Near the Top, Field Side of the Structural Uprights. Impedance Bond Cases Located Between Rails.

The proposed arrangement for carrying the propulsion current through the track circuits was to place a bond from one track circuit to the next, diagonally across the track and between the insulated joints, leaving both of the insulated joints in service. All calculations and preliminary tests seemed to indicate that the propulsion return through the track circuit sections of the road could be handled very well by this scheme, and, accordingly, the installation was made. However, the bonding together of one side of successive track circuits, providing a continuous conductor, unbalanced the track circuits so that foreign current rendered the scheme useless.

Development of the A. C. Frequency Relay

At this point in the development of railway signaling, a.c. track circuits were just being brought out and were suitable only for d.c. propulsion. It was, therefore, necessary to develop an a.c. track circuit scheme which would not function with foreign direct current or 25-cycle alternating propulsion current in the rails. The matter was taken up with the Union Switch and Signal Company, who, after a short period, announced a frequency a.c. track relay and a leakage filler track transformer as suitable to meet the requirements. The chief characteristics of the transformer were that the voltage to the track with a given load could be regulated by raising or lowering an iron filler located within the magnetic circuit, and that it possessed a characteristic whereby, as the current on the secondary coil increased, the potential on the secondary circuit decreased so that it could be connected directly to the rails and suffer no injurious heating by trains standing on the track indefinitely.

The relay was designed to operate the contacts by the rotation of a vane within the magnetic field, but the principal characteristic was its selective property as to frequency. There were two magnetic circuits in the relay, energized by two electric circuits connected in multiple, one of which was more highly inductive than the other, so that with a given potential of 60-cycle current across the coils, it would create a torque in the vane in the proper direction to close the relay contacts, while a 25-cycle current would create a torque in the vane in the opposite direction. There was one inherent difficulty in this relay, from a signal engineering standpoint; in case of internal failure, the relay would not fail on the safe side but would function and an improper indication would result, on account of the fact that if the circuit of higher impedance within the relay became interrupted or broken, 25-cycle current would create sufficient torque by energizing the other coil to close the relay contacts. The selective property was thus dependent upon the integrity of the circuits within the relay.

In connection with the a.c. track circuit equipment, it was necessary to provide a means of carrying the propulsion current around the track insulators. There had already been developed an inductive bond for use in connection with d.c. propulsion system. A modification of this bond, to meet the characteristics of the a.c. propulsion system and suitable to work in connection with the track circuit equipment, was adopted. This bond is described later.

Difficulties on Control Circuits Overcome

It was, therefore, believed that all that was necessary to maintain the integrity of the signal system was to provide a power transmission line of 2,200-volt potential and the necessary track circuit equipment, consisting of the transformers, track relays, and inductive bonds as described above. However, the preliminary tests of single phase transmission for propulsion purposes developed inductive possibilities that had not been previously anticipated. All of the interlocking stations between Stamford and Woodlawn were wired with No. 18 double cotton-covered paraffin insulated wire, suitable for primary battery potential of 12 volts. The electric interlocking between the towers required seven aerial wires which were located on the Western Union poles and

Fig. 2—Duplicate Arrangement of Instruments at Signal Track Transformers, Reactors and Centrifugal Relays on Second and Third Shelf.

connected direct to the cotton-covered wire in the towers. Six of the seven wires were sectionalized at the towers, and, therefore, only continuous from tower to tower, but the seventh, or common wire, was continuous from New Haven to South Mount Vernon. All of the instruments within the interlocking stations functioned with very small currents.

In the matter of protecting the block signal system against the effect of both static and magnetic induction, the latter, being accumulative in proportion to the distance, would reach a comparatively high value on the common wire. There was no precedent and, therefore, it was necessary to develop a scheme to retain the present block signal system, but so modify it as to render it immune against inductive influences. This was accomplished by sectionalizing the common wire at each tower and by insulating the interior circuits from the exterior circuits at each block station. The insulating was accomplished by a scheme of relays in the exterior circuits. The di-electric strength of the relays and aerial lines was designed to withstand, with a good factor of safety, any inductive influence that might be exerted upon them. In fact, as the seven wires were parallel and all of them connected together, either through a battery or relay magnets, the magnetic inductive effect upon one wire exactly balanced the inductive effect upon the adjacent wire, so long as the system was maintained clear of grounds. The system was protected against static induction by lightning arresters that broke down to earth at 500 volts. This work was carried out successfully; so much so that no signal failure has ever been reported as due to inductive influence even in those early days when flashovers and violent surges were common occurrences on the propulsion systems.

Development of the Centrifugal Frequency Relay

During the period between the completion of the electrification to Stamford and the time of extending the electrification from Stamford to New Haven, the development of track circuit equipment to be used in connection with the a.c. propulsion system progressed rapidly; the first progressive stop being the use of an ironless galvanometer track relay on the Harlem River branch in anticipation of future electrification. Safety in operating this relay in connection with 25-cycle propulsion was secured by providing the energy for the track circuits from a power transmission line separate from that which provided the energy for the balance of the signal system. The phase relation of the two transmission lines was held permanent by being furnished from two generators, directly connected and driven by a common motor.

Later the Union Switch and Signal Company developed a frequency vane-type track relay of the single element type, taking all of the energy from the rails and, therefore, extravagant in the use of current as compared with the galvanometer type. It required, however, but one transmission system and its construction was very simple.

During the period of these developments, the Union Switch and Signal Company was also working on the preliminary instruments that have resulted in our present centrifugal frequency relay. The contacts of the centrifugal frequency relay are closed by mechanical energy transmitted from a centrifuge which is lifted by the centrifugal force of revolving weighted arms, which operate in a manner similar to the old ball governor of a steam engine. This revolving member is directly connected to the rotor of a two-phase induction motor. One phase of the motor is energized from the local bus at the signal location, while the other phase is energized by current from the track.

The selective feature of this relay is based upon the synchronous speed of the rotating member as driven by 25-cycle or 60-cycle current. The centrifugal force of the revolving weighted members, when operating by 25-cycle current, is not sufficient to lift the counterweights and close the contacts, but when traveling at a speed resultant from 60-cycle current, there is sufficient centrifugal force to cause the relay contacts to close. This relay not only has the advantage of being the safest type of relay that can be used, but also takes the major part of the required energy from a local bus, only a small part coming from the track. Therefore, it is comparatively economical in its consumption of energy.

Track Transformers Improved to Meet Requirements

During the progress of the track relay development, the track transformer also was improved, and from the oil-cooled leakage filler transformer the air-cooled reactive transformer was developed. The characteristics of this transformer, however, were at first such as to render very poor voltage regulation, so that later an improved method, the one which is now used as standard, was developed; i. e., an air-cooled transformer of good voltage regulation with a reactor connected in series between the track transformer and the track, the reactor being adjustable so as to create the proper phase relation in the two phases of the centrifugal frequency relay. Upon the basis of the modern track transformer, with reactor inductive bond and centrifugal frequency relay as a foundation, the present signal system has been constructed.

In laying out the signal system, a signal circuit was devised with a view of being immune against the effect of induction. This was accomplished by limiting the length of the circuit and by insulating all of the control circuits that extended through the block, maintaining a high di-electric strength by means of transformers and relays. At certain signal towers, the circuits were divided east and west by the use of two transformers, one for circuits in each direction, furnishing energy to the system and by either using transformers or relays for circuits that extended through the signal station. By this means, no wire was of sufficient length to obtain a higher voltage drop to earth (under the most adverse electric conditions of the traction system) than would be permissible with a good factor of safety based upon the insulating properties of the system. Practically all adjacent wires were connected together through transformers or relays so that, being parallel, the inductive effect upon one line was compensated by the inductive effect upon the adjacent line.

Power System Separate from Propulsion

The power for the operation of the entire signal system is furnished from motor-generators, located in the power plant at Cos Cob. There are three 450 KV.A., 2300-volt, 60-cycle generators, driven by 25-cycle induction motors. Any two or all three units may be operated in parallel, furnishing current for the signal system which, at present, is about 700 KV.A. The 60-cycle current is taken single-phase from the generators at 2,300 volts and transformed to 11,000 volts at an out-door substation located between the power plant and the tracks.

The transmission system consists of a duplicate, metallic circuit, 11,000-volt single-phase lines extending east and west from Cos Cob. At New Haven, the current is reduced to 2,300 volts through the city and at New Rochelle Junction, it is reduced to 2,300 volts to Woodlawn and to Sunnyside Yard, over the New York Connecting Railway. Facilities are provided for sectionalizing both pairs of the transmission lines, one of which is located on each side of the right of way on catenary structures. The tower operators, under direction of the load dispatcher, are in a position to cut in or out of service any section of the transmission system. Between New Haven and South Mount Vernon, the signal load is connected to both transmission lines through an automatic switch so arranged that the signal load is taken from one set of feeders normally. By the de-energizing of that set of feeders, automatically the load cuts over to the duplicate service and also automatically restores to the original source when that line is again energized. All of the oil circuit breakers for sectionalizing the supply lines are of the Westinghouse remote control type and the system is thoroughly protected with electrolytic lightning arresters.

Interlocking Stations Re-arranged

With the electrification of the system and the reconstruction of the signal system, it became advantageous to either construct new signal towers or to re-locate existing towers so as to establish a more uniform distance between signal stations. The object of this was to establish at the interlocking stations universal crossovers so as to permit of the directing of traffic and the changing of traffic from one track to another at proper distances and also to provide for the uniform sectionalization of both the traction and signal power systems. These interlocking stations, depending upon the physical conditions, were either all electric, electro-mechanical or mechanical with control of electric signals. All signals operated electrically and at all points approach locking, route locking and detector locking was planned.

The most extensive interlocking system is at Stamford where an all-electric Type-F system was installed. From this point, energy is supplied through the Type-F bus for all signal units and track circuits on all four tracks and the new Canaan track, aggregating a track mileage of approximately 20 miles. Crossovers are operated in the main line tracks 3,000 ft. from the tower. The location of trains at this interlocking, as at all others. is given to the towerman by means of an illuminated track diagram. The switching and transferring of traffic from one track to another over the many of the more distant switches operated from the tower is often conducted out of sight of the towerman.

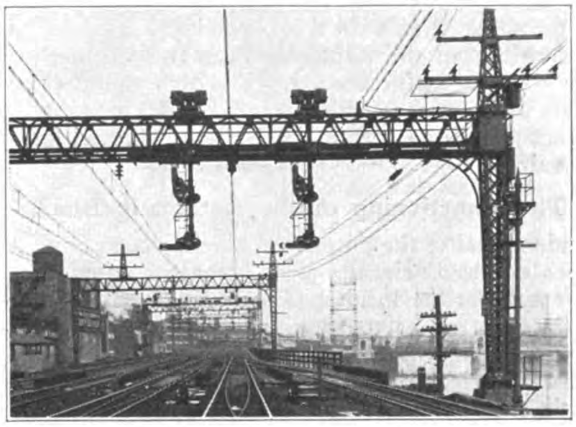

Fig. 3—Typical Signal Installation at Interlocking. The High Towers in the Distance Carry the Signal and Propulsion Transmission Lines Over a Navigable Stream at Bridgeport, Conn.

A. C. Semaphore Signals Used

Practically all of the signals used in the electrified zone are of the motor-driven type, there being a few color-light signals in New Haven Terminal. During the period of reconstruction, color-light signals were considered. It was thought that that type of signal would give a more conspicuous aspect suspended from the catenary structure, but at that time the color light signal had not been developed to a point that would warrant such an extensive application. Therefore, the motor-driven signal was adopted. However, with a high-powered semaphore lamp, which was especially developed for this purpose, these signals are practically converted into a color-light type. The beam candle power of this lamp is approximately 7,000, when not transmitted through a colored roundel. The intensity of light is so great that the voltage is reduced to one-half at sundown. This is accomplished by a circuit controlling a relay at each signal location.

Track Circuits

Track circuits are equipped with the modern track circuit equipment, as outlined above. The maximum length of track circuit is 4,000 ft., regardless of the length of the block. Cross bonding for the propulsion return is not permitted at the cut sections, but only at signal locations. It was necessary to limit the cross bonding in order to provide a reasonable surety of broken rail protection, because the cross bonding at the end of each track circuit section formed a metallic connection to the rails of the adjacent tracks, with the result that the cross bonding and these rails would form a shunt around any point in the rail of the track circuit where a break might occur. Limiting the cross bonding to the signal locations, so increased the resistance of the metallic connection in multiple, with the rails of the track circuit, that the current in the track relay, in case of a broken rail, would be reduced below an operating value.

The adjacent track circuit polarities are reversed so that, in case of a broken down insulation of an insulated joint, the current from the track transformer entering the relay of an adjacent track circuit would reverse the torque in the relay rotor; the mechanical design of the relay being such as to prevent the movement of the rotor in the reverse direction. If the adjacent track circuits were the same, then with a broken down insulated joint, the energy from the adjacent track transformer would create a torque in the track relay, which would close the contacts as soon as a train had traveled far enough into the track circuit to permit the current to reach an operating value.

The Functioning of the Automatic Block

Fundamentally, the automatic block system consists of a series of track circuits which control automatic signals at appropriate locations; one block control overlapping the next so as to provide advance information to the approaching enginemen.

The track circuit consists of the following: Insulated joints in the rails to establish the limits of the track circuit, the track transformer to supply current to the track circuit, the track relay, and the reactor, the object of which is: first, to establish the proper phase relation in the track relay, and second, to create a choking effect when the track is occupied by a train. The track circuit is established as follows: (Fig. 4). From the track

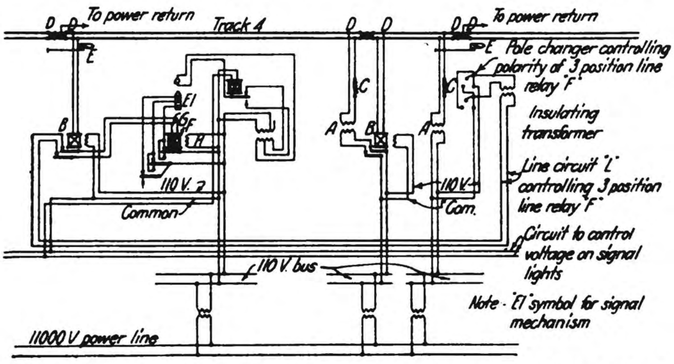

Fig. 4—Diagrammatic Sketch of the Circuits for One Block; Note the Cut Section Dividing the Block Into Two Track Circuits and That There Is No Power Return Connection at This Point.

transformer "A," through a lead to one of the rails of the track circuit, from that rail to the relay coil "B," thence back to the other rail of the track circuit, thence back to the track transformer through the reactor "C."

In order to provide for the power return around the insulated joints the inductive bonds "D," mentioned above, are placed at each end of each track circuit. The inductive bond is similar to a large choke coil with an iron core, having three terminals, one from each end of the coil and one from the middle of the winding. The end terminals are connected to the rails and the middle terminal is connected to a similar terminal of the bond in the next track circuit. The coil connected across the track offers considerable impedance to the 60-cycle signal current, but the 25-cycle propulsion current entering both ends of the coil and passing out through the middle terminal to the next impedance bonds, does not create any reactance in the coil; the only resistance to the propulsion current, therefore, is ohmic. The bond, as connected, has practically the same resistance as the regular rail joint bond.

At the entering end of the block there is a motor-driven signal E. The circuit for the operation of the signal is as follows: From the bus bar at the location, through the contacts of a three-position or polarized line relay F, hereinafter mentioned, thence to the signal mechanism, indicated as E1, and thence back through the other contacts of the three-position line relay, and then back to the bus bar.

The signal mechanism is provided with a combination of contacts so arranged that in the horizontal, or "stop" indication, the contacts are in a given position, but when the signal assumes the 45 deg. or "caution" indication, or the 90 deg. or proceed indication, the contacts are in another position. The position of these contacts controls the polarity of energy to a line circuit L, at the far end of which is located the three position line relay F, mentioned as controlling the signal circuit.

The three-position line relay F is designed with two coils, one H permanently energized from the local bus and the other G from the line circuit. The line circuit passes through the contacts of the track relay and, as outlined above, is subject to change in polarity. The functioning of the contacts for the control of the signal is as follows: When the line phase is de-energized by the opening of the track relay contacts, the moving member assumes a position by gravity, so that neither the front nor the back contacts are closed. This interrupts the circuit to the signal mechanism which in turn, by gravity, assumes the most restrictive indication.

By energizing the line relay in one polarity, it will close two contacts through which the energy from the bus is transmitted to the signal mechanism and causes the signal to display the 45 deg. aspect, as caution. With the change of polarity of the line circuit, the moving member of the relay reverses its position, closing three contacts to the signal mechanism, which, in turn, responds by traveling to the 90-deg. as proceed indication.

In studying the effect upon the signal circuits of the presence of a train, assume there are two blocks identically alike. The train is passing from the first to the second block. While the train is in the block, the wheels and axles form a metallic connection from one rail to the other. This connection is in multiple with the track phase of the track relay and being of very low resistance, shunts the energy from that coil of the track relay. The de-energizing of the track relay and the opening of its contacts causes the de-energization of the three-position line relay and the opening of the contacts of that relay, interrupting the signal circuit. The result is, with the train in the block, that the signal will assume, by gravity, the most restrictive indication. In passing from the first block into the second, the front wheels of the locomotive cause the track relay of the second block to release the signal at this location, thereby assuming the stop indication. With the passing of the last wheels of the train over the insulated joints into the second block, the first block track circuit is again energized. This causes the track relay of the first block to function, the contacts to close, the three-position line relay to function and the signal mechanism to operate. However, the polarity of the current to the line relay has been reversed by the signal in the second block assuming the stop indication. The changing of this polarity and the reversing of the three-position, or polarized, relay at the signal station in the first block, causes that signal to travel only from 0 to 45 deg., indicating caution.

It is, therefore, obvious that the train is protected by two signals; the first in the direction of traffic, indicating caution, and the second signal protecting the train, indicating stop. As the train passes out of the second block and the signal of that block goes to the 45-deg. position, the polarity contacts change to normal, and the polarized relay at the signal of the first block again assumes its normal position, thus causing the signal to travel to the 90-deg. or proceed position.

At interlocking stations, routes are controlled, interlocking levers are locked and switches are locked by the presence of a train upon a given track circuit controlling a track relay, which, in turn, interrupts the circuits of such locks. The locks are electrically operated and when de-energized, the lock of the various units is effective. It is, therefore, obvious that to release any of the operating units, it is necessary to establish the predetermined circuits in order to energize the respective locks.

The position of signals and the position of the electrically operated switches control circuits through the interlocking plant for the purpose of establishing an electric interlocking between the units to prevent them from functioning in such a way as to create a confliction of traffic. That is, with a certain route established, the electric circuits are such as to prevent the tower operator from giving any proceed signal indications over a route that would conflict with the route that is established and conversely, if any signals permitting traffic over a given route shall fail to assume the most restrictive indication, when operated from the interlocking machine, the circuit will continue interrupted and prevent the changing of that route.

The 700 kv.a. of energy from the generators at Cos Cob is distributed over 132 miles of power lines and 24 miles of power cables, along 89 miles of railroad, having 344 miles of signaled tracks and is transformed by 1,718 transformers ranging from 20 v.a. to 225 kv.a. in connection with the operation of 940 track circuits, 1,215 signal arms lighted by 1,215 high powered electric lights and 133 electrically operated switch units. There are 36 interlocking stations having 1,425 working levers and in connection with which there are 709 storage battery cells floated across 11 motor-generators, all of which are connected together by 175 miles of low voltage aerial cable.

Enforced Stop Signals

The Philadelphia Rapid Transit Company has recently made an installation of automatic block signals possessing somewhat unique functions and which is particularly useful for electric railways where long, dangerous, winding grades exist. At the end of the double-track Germantown avenue line, from Chestnut Hill to the city line, for a distance of about ¾ of a mile, there is a grade, which is deceptive, producing the impression that the down grade is not as severe as it really is. Two shuttle extensions of line No, 23 use this trackage, one marked City Line, and the other Erdenheim, the latter branching off of Germantown extension.

There were formerly six safety stops, located at regular intervals along the Germantown avenue grade; and it required considerable supervision to see that these safety stops were always observed. The transit company installed the automatic signals to insure that these stops be made. There are six blocks of signals in all, the city line cars passing all six, and the Erdenheim branching off after the fourth signal.

Each block of signals consists of a two-indication normal danger signal, showing a red light normally, which must be changed to green in the sight of the motorman before his car passes the signal to enter the block. The installation comprises a setting contactor at the signal, a preliminary contactor about 100 ft. in the rear of the signal, and a clearing contactor, which also forms the setting contactor of the block in advance.

When the trolley wheel of the car passes under the preliminary contactor, the motorman is then only about 50 ft. from the signal indication. The contact of the wheel with the contactor starts the time element relay in operation, so that five seconds thereafter, as the relay is adjusted, the signal changes to green, provided, however, there is no car in the block he is about to enter. He must, therefore, bring his car to a stop, or practically so, in order to see the green signal appear before he passes it. As soon as he passes the signal his trolley wheel touching another contactor which throws on the red again, the normal indication. However, while he is still in the block should a second motorman pass under the preliminary contactor he (the second one can not obtain a green signal until the first car is out of the block. Thus the signal not only causes a safety stop to be made, but also gives rear protection.

Light Signal on Trolley Line to Enforce and Record Safety Stops on Grades

To insure that the motorman shall not pass a signal at stop, such as he would do if he did not remain within the preliminary, the required 5 sec., a Nachod automatic headway recorder is connected to the signals so that all cars passing the signal at green register on one side of the record sheet, and all cars passing the signal (improperly) at red, register on the other side. The chart is renewed daily showing the exact time that these passages were made. With this novel application of the recorder the motorman either makes the safety stop, or permits himself to be recorded as not having made it.

The illustration shows a view of the signals, which gives indications through 6⅜ in. diameter hooded lenses, with 23-watt headlight lamps. Both lights and relays receive power from the 600-volt trolley. The signal relays are mounted on the pole switchboard style, enclosed in a box with removable sides, thus giving ready accessibility. Duplex, neutral, slow-release and time element relays are used. The time element relay is not affected by voltage or temperature, and may be set from 1 to 15 sec. These signals are manufactured and installed under the supervision of the Nachod Signal Company, Inc., of Louisville, Ky.