This invention relates to improvements in train dispatching systems, and more particularly to an improved communication arrangement between the control station and the substations connected therewith.

In the train dispatching system to which the present invention is applied, a control station is connected through a single circuit with a plurality of substations in such a manner that by means of suitable units, train signaling, track switching, and other traffic regulating operations and the like, may be performed at any one of the substations in accordance with instructions transmitted from the control station. The control station is also apprised of the track and roadbed signal conditions by means of so-called OS indications, i.e., by means of impulses generated at the control station and affecting indicators thereat but modified by the condition of the traffic regulating devices at the substations. The communication is by coded impulses directing a substitution to perform certain operations or, at the will of the control station operator, informing the latter whether instructions have been carried out at a particular station. Thus, the control station automatically and periodically tests traffic regulating conditions at all the substations, i.e., obtains information on the positions of track switches, semaphore, track relays, etc.

If it is desired to effect changes at a substation, the operator at the control station adjusts an impulse transmitter to send code symbols typical for the desired substation and the operations to be performed thereat. A receiver is provided at each substation but only the receiver of the desired substation shall respond and actuate the associated control units in accordance with the code symbols. For the sake of economy and rapidity of communication, the stations are interconnected by a single circuit over which time channels are established through which various stages of the communicating are performed. A definition of this term is given at the end of this specification. In accordance with one embodiment of the invention, the time channels are used in overlapping groups, i.e., the same time channel may serve in two different codes directed to two different results.

The time channels are used also for the purpose of conveying report signals to the control station. The traffic governing devices at the substations are associated with the control circuit over certain channels to actuate receivers at the control station in accordance with code impulses that have originated at the control station. During the same channel both control and report symbols may be sent. The faithful cooperation of the control station and substation equipments is insured by synchronously establishing the channels through which the communication takes place and making effective only those substation channels through which communication should take place.

It will be obvious to those skilled in the art that the present invention may be modified in many respects without exceeding the scope of the appended claims. The dial and distributing switches may be provided with contacts that cooperate with each other in response to other than rotary motions. In fact, any electromechanical circuit switching arrangement may answer the purpose. The expressions “dial switches”, “distributor switches”, and the like, were arbitrarily chosen and are intended to apply to any circuit switching device suitable for the purpose. Similarly, the connections to the brushes and stationary contacts of the switches and distributors may be reversed, the lamps, polarized relays and the like replaced by other suitable devices, etc. In the systems herein described, direct current is used for certain, and alternating current for other phases of the communicating and control operations. This also may be modified and varied to suit particular operating requirements. The synchronizing arrangements may be replaced by other arrangements which will insure the timely cooperation between the control station and the substations. The rail switches, track relays and semaphores, which are defined as traffic governing devices, may be altered or supplemented by other traffic governing or testing devices, etc.

These and other departures from the specific exemplification of the invention will be apparent to those who may wish to employ the constructive features of the invention. Most of these features are applicable to train dispatching systems of widely varying character and need not be employed in totality.

These and other features are diagrammatically illustrated in the accompanying drawings, only those parts of a train dispatching system being shown which are necessary for explaining to one skilled in the art in one manner in which the invention may be practiced.

Fig. 1 shows the relation of the central control station, the line, the substations, and the operating units controlled thereby;

Fig. 2 shows in an elementary form means by which communicating time channels may be established between the central station and each operating unit in turn;

Fig. 3 and Fig. 4, respectively, show arrangements for utilizing these channels to control a track switch and to control a group of roadside signals;

Fig. 5 shows an arrangement for transmitting over one channel a report indicating the position of an operated unit;

Fig. 6 shows sending and receiving devices at the central station involving further refinements.
whereby a greater number of control or report symbols may be transmitted in a given time;

Fig. 7 shows a detail modification of Fig. 6;

Fig. 8 shows means for maintaining synchronism of the substation apparatus with the central station;

Figs. 9 and 10 show arrangements provided at a substation for receiving control symbols and for characteristically affecting report symbols sent from the central station.

Fig. 11 shows a modified system in which direct current impulses are sent for control, and alternating current impulses for report symbols;

Fig. 11a is a detail of Fig. 11;

Figs. 12, 13, and 14 illustrate the system in which the time channels are arranged in overlapping groups, and

Fig. 15 is a combination of Figs. 11 and 12.

The same reference numerals occurring in various figures designate identical or similarly functioning apparatus.

Referring to the drawings, Fig. 1 is a single line diagram indicating the major units involved in the system. 1 is a central control station from which all other units are controlled and to which their positions are automatically reported. 2, 3, and 4 are substations scattered along the railway route to interpret symbols transmitted from the central station and control adjoining groups of controlled or operating units, and to transmit to the control station reports indicating the actual positions of controlled units. 5 is a control channel which, in the present example, is constituted by a line circuit connecting the central station to all substations. It is grounded at its far end. 10 is a grounded battery at the central station which originates the energy for control and report symbols.

The central station comprises three sections or substation control panels, 12, 13, and 14, on which are localized the control and indicating units for substations 2, 3, and 4, respectively.

At each substation there is a track relay 16, to indicate whether an adjoining track section is clear or occupied. At the top of each central station section there is an indicating lamp 49 to indicate the position of the corresponding track relay.

The indicating lamps are located in sections of a track diagram to show visually the relation of the section indicated to the actual tracks.

Substations 3 and 4 are shown semaphore 17, adapted to operate in three positions, viz: vertical, as at substation 3; inclined, as at substation 4; or horizontal. In the corresponding sections of the central station are control handles 53 having three operating positions corresponding to the three positions of the semaphores or road side signals; and immediately above are three indicating lamps, one of which is lit to indicate the position actually occupied by the semaphore. Instead of a single semaphore as drawn at each substation, there may be a group of such adapted to be set up in three combined positions such as "clear for eastbound movement", "clear for westbound movement", and "stop".

At substations 3 and 4 there are also power operating machines 18-18 for operating track switches, and at the central station are corresponding operating handles 55, 55, each operable to two positions "normal" and "reversed"; but associated with each operating handle are three indicating lamps, as in the case of signal control handles. The left- and right-hand lamps successively indicate that the track switch is closed and locked in its normal or reversed position. The middle lamp indicates that the track switch is open or unlocked, which is understood to be that it is in the process of throwing over or that it has failed to complete its stroke and lock up ready for the passage of a train.

Each operated or reported unit 16, 17, or 18 is shown connected to its substation by a single wire; but it is understood that any number of wires necessary for the desired control and reports may be employed. These connections are local and short. In addition to the units 16, 17, and 18, there may be also other traffic regulating or indicating devices associated with the substations. The single control wire 9 with ground return as 15 shown (or with metallic return), is sufficient for transmitting all necessary control and report symbols between the central station and the substations.

At each substation is shown a local battery 19 to furnish power for operating the track switches, railway signals and reporting mechanisms, subject to control symbols transmitted over the line circuit 8.

One section of the central station is thus actively adapted to control a typical group of railway traffic regulating or indicating units comprising one track switch (or group of switches working simultaneously), and one roadside signal or group of signals, and also adapted for receiving reports which indicate one of three conditions for each. In addition, it is adapted to receive reports indicating the position of one track relay. Part of these units may be omitted, as in section 12, or other units up to the equivalent of the units associated with the typical section may be included.

Fig. 2 shows an elementary form of means by which a number of communication channels may be established successively between the central station and substations. 6 is a motor at the central station receiving power from battery 7 and driving a shaft 20 continuously. 8 designates a governor mounted on the shaft comprising centrifugal brake shoes 5 revolving within a stationary ring 11. At a predetermined speed the brake shoes are thrown into frictional engagement with the ring 11 by centrifugal force and further increase of speed is thereby precluded.

Mounted upon the shaft 20 and insulated therefrom are six movable contacts or brush arms 2-2 constituting, with the associated groups of stationary contacts, six dial switches 21, 22, 23, 24, 25, and 26. A cam 27 also mounted upon the shaft 20 controls a follower 28 spring-biased toward the cam. The follower controls a pawl 29 which actuates a six-tooth ratchet 37 in such a manner that the latter advances one step at the end of each revolution of the shaft 20, and completes one revolution or cycle in six steps. The dial switches 21-26 perform one complete revolution upon each revolution of shaft 20, or six revolutions per cycle of ratchet 37. 39 designates a shaft driver for the ratchet 37, and 31 designates a six-point distributor dial switch having its movable contact or brush arm mounted upon the shaft 30 and insulated therefrom. The last mentioned brush arm is connected to a conductor 9, which is the control line 9 of Fig. 1. The stationary contacts or segments I, II, III, etc., of distributor 31, as the brush arm revolves, connect the line 9 successively to the brush arms of dial switches 21, 22, 23, 24, 25, and 26, each of which in turn, during the time it is connected to the line, connects successively with its own group of segments a, b, c, 70
The brush arms of switches 21, 22, 23, 24, 25, and 26 are aligned to contact simultaneously with their corresponding group of segments, as illustrated, each brush arm contacts with its segment a. During six revolutions of the shaft 20 the control line 9 will be connected successively to each segment of switch 21, then to each segment of switches 22, 23, 24, 25, and 26 in turn.

Switches 2, 22, 23, 24, 25, and 26, respectively, are a motor, a battery, a shaft, and a governor, similar to the parts 6, 7, 20, and 8 already described, but located at a substation along the railway. 63 designates a sleeve mounted upon the shaft 60 and driven thereby through friction. Upon this sleeve are mounted the insulated movable contact or brush arm of a distributor switch 61 and a single tooth ratchet 62. The latter may be engaged by a detent 65, biased toward the ratchet by a compression spring 65, or the detent may be disengaged by the energizing of a magnet winding 66. A second sleeve 61 friction driven from the shaft 60, carries a single tooth ratchet 62 and a cam 64. The latter actuates a follower 72, a pawl 73, and the pawl in turn a ratchet 74, similar to the parts 28, 29, and 31 already described. The ratchet 74 drives a shaft 85 and, by the intervention of friction, a sleeve 70 mounted thereon. Upon the latter are mounted the insulated movable contact or brush arm of a six-point distributor switch 71, and a single tooth ratchet 75. After making one revolution the ratchet (with the sleeve 70 and the brush arm of 71) is stopped by a spring-biased detent 76 until released by current in the magnet coil 77. A second detent 83 is coupled to detent 76 by a link 84 and can engage the ratchet 82 only when detent 76 drops into notch of 75, i.e., after six revolutions of ratchet 82 and one of ratchet 75. When engaged, detent 83 restrains the cam 64 against further movement until released by the coil 77. Current for the coil 71 is supplied by a battery 78 and controlled by a polar relay 79 in series with the line 9, so arranged as to close its contact only when current flows through the line from the negative pole of a battery. Each of the switches 21 to 26 is shown for illustration with five equally spaced stationary contact segments, each having space from the fifth segment to the first. The distributor switch 61 is shown with five stationary contact segments all symmetrically spaced in a group. In practice, all of these dial switches may have a larger number of stationary contact groups such as eleven. The governors 8 and 88 are so adjusted that the brush arms they control will advance from the first segment a to the fifth segment in approximately equal time, but owing to the increased space from the fifth segment to the starting point on switches 21 to 26, they will be somewhat later in returning to the starting point than distributor 61 or at least in no case, even with the maximum deviations from normal speed, will the latter arrive at the starting point later than the former.

All parts are shown at an instant when the dial switches 21 to 26 have just reached their starting point on segment a. The cam 21 acting through the follower, pawl, and ratchet 28 and 29 and 37 has just advanced the distributor 31 to the stationary contact segment I., and the line 3 is thereby connected through segment a of distributor 21 to the negative pole of battery 54, which is grounded at its midpoint. Before this instant, distributors 61 and 71 at the substation have advanced to segments a and I., respectively, establishing a circuit from grounded battery 54 at the central station through distributors 21 and 31, line 9, the coil of relay 79, distributors 71 and 61, and through the winding of starting magnet 65 and the next section of line 9 to the succeeding substations, and ultimately to ground at the end of the line, as shown in Fig. 1. Since the battery connection, as stated, was at the negative pole, current through polar relay 79 is of negative polarity and the relay contact is closed, energizing magnet 77 by current from battery 78 to release the detector 78 and 83 which just previously held distributor 71 and the cam 61 at their starting positions. This occurs at all substations. At the same time, the line current passing through magnet 69 has withdrawn the detent 83 which just previously held distributor 61. This occurs only at one substation at a time in the illustration. It is about to occur at the one shown. Thus at the illustrated substation and instant two independently releasable elements are started rotating together and in step with "central". These are: first, shaft 81 with stop ratchet 82 and cam 84, which always revolves six times per clockwise revolution, giving six steps or one revolution to distributor 71; second, distributor 61, which makes one revolution in one-sixth of the cycle and is still during the same time. Because it is contact I of distributor 71 that is connected to distributor 61 in the substation shown, the latter makes its revolution in the first sixth of the complete cycle. At the five other substations distributors 61 would be connected, respectively, to contacts II, III—VI, of their respective distributors 71. Distributors 61 in the six substations thus make single revolutions each in a different sixth of the full cycle, and in step with one of the six revolutions of dials 21—26. In this revolution line 9 first connects segment a of 61 and a of the corresponding central office dial 21 (as shown), or 22, or 23, etc.; then b and b, etc. Thus in each cycle five instants of electrical continuity (over line 9) exist between five central office and five substation conductors in a fixed one-to-one correspondence. This is frequently called dividing line time into channels. Time of this kind may be spoken of and treated like separate wires, with the one limitation that no two coexist in time. Of each five channels one (a) is being used for the self-protective purpose of starting substation dials in synchronism (more properly, "in phase") with central office dials, there remain four to each substation for use, i.e., twenty-four "pay load" channels per cycle. Fig. 2 shows simple novel means for creating and protecting a number of individual usable channels between one central and each of several subsidiary stations, but without regard to how they may be used.

Summarizing more concretely, dial switches 22 to 26 in turn will be connected to the control line 9 during the five revolutions in which distributor 61 is locked. During each of these revolutions a different distributor at a different substation may be connected to the line and may function precisely as here described, except that a different segment of the group of stationary contacts on each distributor 71 will be connected to the corresponding distributor 61 with the result that the latter will function during a different revolution of the shaft 28. Thus we may have as many substations as we have stationary contact segments on distributor 31; a dial switch for each substation being required on the shaft 28.
and there being set up with each substation as many communication time channels, successively established, with the central station over line circuit 9, as there are stationary segments on each of dial switches 21, 22 to 26, on each dis-

tributor 61.

It should be observed that the negative pole of battery 54 is connected to the starting seg-

ment a only at distributor 21, while the corre-

sponding segments of distributors 22 to 26 are connected to the positive pole of battery. Since the relay 79 and the corresponding relays at other substation respond only to negative cur-

rent, it follows that all revolution counting dis-

tributors 71 will be started in step simultaneously

only during the first revolution of each cycle.

Hence, even if the entire system be thrown out of

step (so long as the motors 66 continue to run), all substation distributors will run up to

the starting position and stop at some time

during the first six revolutions of the shaft 20.

At the beginning of the next succeeding cycle all

will start again in unison.

Fig. 3 shows connections which may be made

over two channels to control a track switch in two

positions. Current passes from ground, through
central battery 54, to one of two points of selector

switch 55, at central station, thence (at the in-

stant when they are connected to the line), over

one of two segments at central switch 21 to the

control line 9, then by one of two segments in

substation distributor 61, through a local con-

trol circuit, to a relay operating coil 86 or 89, and

so to ground. As shown, 86 was the coil last

energized and its contact finger 88 is closed to the

front contact where it is held by current passing

from ground through substation battery 19, throu-

g the front contact of finger 88 to a holding

coil 87, thence through a back contact of

finger 92 of relay 88 to the normal operating

wire 94 of the track switch machine, and so to

ground. It is understood that a relay or other

contact at the track switch machine must remain

continuously closed while the track switch is in

its normal position to maintain current through

the holding coil 87.

If the selector switch 55 be now reversed and

sufficient time elapse for the switch 21 and dis-

tributor 61 to resolve to the corresponding posi-

tion, current will pass through the second local

control circuit to the operating coil 89, closing

contact 91 and opening contact 92 which inter-

rupts the holding circuit through coil 87 and

allows back contact at 88 to close. Thus a hold-

ing circuit is established from battery 19 through

fingers 88 and 91 and the holding coil 90 to the

reverse operating wire 93; and in general, when

either operating coil 86 or operating coil 89 is

energized momentarily, it interrupts the holding

circuit of the other relay and establishes a hold-

ing circuit for its own relay; so that a momentary

impulse through the one coil or the other serves
to establish one or the other of the operating cir-


cuits, and the circuit established is maintained

until superseded by energizing the other operat-

ing coil.

Obviously, instead of two track switch or

roadside signal operations, switch 21 and dis-

tributor 61 may jointly control three or more

operations. Fig. 4, for instance, shows roadside

signal operating circuits controlled over three

channels or control wires of selectors 21 and 61, in

accordance with the position of three-way

selector switch 53. The diagram shows connec-

tions as they exist at the instant when the con-
trol circuit is closed through the upper contact

of the selector switch and the corresponding seg-

ments of switch 21 and distributor 61, to relay

operating coil 88. The back contact at 87 being

open, interrupts the holding circuits for relay

98 and 102, which are therefore deenergized at

the same time, and a holding circuit is estab-

lished through the front contact of coil 97, coil

99, and back contacts at 101 and 106, to eastbound
operating wire 108. Operating wire 109 passes

through any necessary relays (not shown) for

establishing a roadside signal set up for east-

bound train movements, and finally to ground.

If operating coil 98 is energized, the holding

circuits for 95 and 102 are interrupted at back

contacts of 101 and 105, respectively, and a hold-

ing circuit for 98 is established through front

contact 100, coil 99, and back contacts 97 and

105, to the "stop" operating wire 108 which passes

through the necessary relays to ground, setting

to all roadside signals at "stop." It is understood

that the local roadside signal control circuits are

arranged in accordance with customary railway

signal practice to indicate "stop" automatically

by failure of current or by any unsafe local con-

dition. The energized circuit here described

serves only for setting the roadside signals to

"stop" by the initiative of the central control

operator at a time when local conditions

would permit them to indicate "proceed".

If operating coil 102 is energized, it causes the

holding circuits associated with 95 and 98, re-

spectively, to be interrupted at back contacts

106 and 105. At the same time, it establishes its

own holding circuit through front contact 104

and back contacts 107 and 106, through holding

circuit 103 and operating wire 107 (which includes

the necessary relays to establish the roadside

signal set up for westbound train movements), to

ground.

Thus any one of the operating coils 95, 98, or

102, when energized momentarily, interrupts the

holding circuit which may previously have exis-
ted for one of the other relays and establishes its

own holding circuit, which holds its contact

closed thereafter until released by energy in an

other operating coil.

Fig. 5 shows a distributor channel connected for

transmitting one of two report symbols from a

substation to the central station, by the use of

central station energy. 105 is a contact inserted

in the control line 9 when the latter passes

through one segment of the distributor 61. For

example, 105 may be a contact of track relay

16 in Fig. 1, whose position it is desired to re-

port at the central station. At the same in-

stant dial switch 21 at the central station con-

nects the line through the relay of polar relay

105 (which is of negligible resistance), to the posi-

tive pole of 25-volt battery 107, which is ground-

ed at its negative pole. A branch circuit con-

nects the line through 1000-ohm resistance 112

to the positive pole of 50-volt battery 54, the

negative pole of which is grounded.

When the contact 105 is open, as shown, there

is a single closed circuit extending from ground

through battery 54, resister 112 and distributor

21 to the coil of relay 108, and thence through

battery 107, to ground. The two batteries being

Opposed in this circuit, the net voltage in the cir-

cuit is the difference of their potentials, viz.: 25

volts. Resistance of all parts of the circuit

other than resistor 112 is relatively negligi-

ble. Hence the current flowing is 25×1000=0.025

amperes, passing upward through the coil of re-


lay 108. The latter is so connected that current in this direction will throw its moving contact to the left or open position, and the relay is designed to have a substantial bias toward either operated position, so that it will remain open or closed as the case may be, until reversed by opposite current through the operating coil. Hence either position is established during one momentary closure of the circuit at distributor 21 persists until reversed by opposite current during some subsequent closure of the distributor contact.

If the contact 109 is closed at the instant when the channel illustrated is established, the voltage of the battery 107, viz., 25 volts, will be applied to the line at dial switch 21 without appreciable intervening resistance. For illustration, the total line resistance is assumed to be 500 ohms. The current through the line will be 25×500=0.05 amperes. The battery 107 is holding the switch 21 at a potential 25 volts above the ground, irrespective of current flowing. The battery 54 is maintaining its positive pole 50 volts above the ground, or 25 volts above the distributor. Hence there will be a current of 25×1000=0.025 ampere flowing into the line through resistor 12. The remainder of the line current, viz: 0.025 ampere, must flow downstream from battery 107 through the coil of relay 108. Hence the moving contact of relay 108 will move to its right-hand or closed position and remain there until reversed by current. A circuit will thus be established through battery 111 and indicating lamp 110 will burn so long as each succeeding revolution of distributor 61 and switch 21 finds the contact 109 closed.

As previously stated, reports and indications are designed for three positions of each track switch and each group of roadside signals. In these cases two channels, two contacts like 108, and two relays like 108 may be employed, each relay following the position of one contact 108. There are thus four possible combinations of open and closed positions at the two contacts 109, and consequently four combinations of positions at the two relays 108. By the use of well-known connections of the relay contacts three of these four combinations may be used to produce the desired indications at the indicating lamps.

Referring now to Fig. 6 which shows typical parts of a central control station, including refinements providing for more controlled and reporting units within a given time cycle, 20 is a shaft driven at accurately constant speed (for example, one revolution per 0.2 second), 21, 22, 23, 24, 25, and 26 are six dial switches mounted on (and insulated from) the shaft 20, each consisting of a revolving brush arm 2 and a group of nine contact segments or spaces lettered a to i. The brush arms 2 are so positioned that all make contact simultaneously with similarly lettered segments (or blank spaces); for example, at the instant illustrated by Fig. 6, each brush arm is in contact with its segment g. Means for driving the shaft 20, shown, may be provided, for example, to a motor provided with a centrifugal brake to limit it to a definite speed. 20 is a second shaft advancing one step for each revolution of the shaft 20, three steps constituting a complete revolution of the shaft 20. Means for driving the shaft 30 are shown, but many well known mechanisms are available for the purpose, such as a three-tooth ratchet, a pawl and a cam on the shaft 20 adapted to move the pawl at the end of each revolution of 20, advancing the ratchet by one tooth; or a source of continuous torque applied to the shaft 30, a three-tooth escape wheel on the shaft, and an escapement actuated by the shaft 20 to permit one tooth advance for every revolution of the latter shaft. Mounted on the shaft 30 and insulated therefrom are three brush arms 2 associated with distributor dials 22 and 23. 9 is the control wire extending throughout the controlled territory and grounded at the far end. A double throw manually operated switch 40 connects the line at will to the brush arm of dial 23 (as shown) or directly to the segment of the same dial, and thence to the line of dial 23. At the instant illustrated, and the position illustrated for switch 40, the line is connected through segment g, i of dial 23 through neutral relay coil 41 and polar relay coil 42, to the positive pole of battery 44. The battery is also connected through a coil 43 opposed to the coil 42, and through an artificial line or resistor 45 to ground. At the instant illustrated (and as described hereafter), the line 8 traverses a loop circuit associated with one controlled unit (at a substitution) this loop having three branches, each indicating one state of a controlled unit 25 (e.g., a semaphore) at this substitution, viz: closed through low resistance, closed through high resistance, and open circuit. In the case illustrated, assume the loop circuit connected into line 9 is in the first condition; current passing from battery 44 through relay coils 42 and 41 to the line is a maximum. The resistor 45 is so adjusted that the magnetizing force exercised by the coil 43 under this condition exceeds that exerted by the constant current passing through coil 43 to the resistor; and the upper contact of the polar relay is closed. The upper, or energized, contact of the neutral relay 41 is also closed.

The high resistance in the second condition of the loop circuit is so chosen that it will reduce the magnetizing force, due to line current through the coil 42, to a value less than that in coil 43, with the result that the lower contact of the polar relay will close, but the neutral relay 41 will still be closed at its upper contact. However, if the line circuit is broken at the substitution loop, both relays will be closed at their lower contacts.

The upper points of relays 41 and 42 are connected to the positive pole of battery 52 and the lower points to the negative pole, the midpoints of 50 the battery being grounded, so that the moving contacts are positive when up, negative when down. At the instant illustrated the moving contact of the polar relay is connected through brush arm 2 and segment g of dial switch 21, through coil of polar relay 46 and through segment i and brush arm 2 of distributor dial 31, to ground. The polar relay 46 is designed to have a substantial bias toward its last operated position, so that either contact when closed remains closed until reversed by reversal of current in the operating coil. So long as the circuit just described is maintained, the relay 46 is closed to its left-hand contact when the upper contact of 42 is closed, and to the right-hand contact when the lower contact of 42 is closed. If the operating circuit through 46 is then interrupted, its contact remains closed at the last operated position until the operating circuit is re-established with the contact of relay 42 in the opposite position. In like manner, the moving contact of relay 41 is connected through the brush arm and the segment g of dial switch 22, through the coil of polar relay 47 and through segment i and brush arm 2 of distributor dial 32 to ground. At the instant
illustrated, when the dials 21 and 22 are closed through segments g—g and the distributor dials 31 and 32 are closed through segments I—I, the polar relays 46 and 47 thus assume positions which repeat the positions (at that instant) of relays 42 and 41. When the distributor and dial switch arms have moved on to other segments, the relays 46 and 47 maintain their operated positions until the next occasion when their operating circuits are closed through segments g—g and I—I.

The moving contact of relay 47 is connected to the positive pole of battery 48, the negative pole being grounded. The right-hand stationary contact is connected through an indicating lamp 49 to the ground. The left-hand contact is connected to the moving contact of the relay 46 and thence, according to the position of the latter, either through the right-hand contact and indicating lamp 50 to ground, or through the left-hand contact and indicating lamp 51 to ground. Since the relays 46 and 47 repeat the positions of relays 42 and 41, and since the latter are dependent on the resistance of the loop circuit which is connected at that instant in the line, the indicating lamps 49, 50, and 51 indicate the connection (or absence of connection) through the loop circuit at the instant when connections are established as described; if the loop circuit is open, neutral relay 41 will be down and indicating lamp 49 will light; if the loop circuit is closed through high resistance, relay 41 will be up and relay 42 down, under which condition indicating lamp 50 will light; if the loop circuit is closed through low resistance, relays 41 and 42 will be up and indicating lamp 51 will light. Furthermore, after the operating circuit through the coils of relays 46 and 47 has been interrupted at the distributor dials 21, 22, the lighted lamp will continue to burn until the operating circuit is reestablished, at which time the resistance of the substitution loop circuit will again determine which of the three indicating lamps shall light.

As described, the indicating lamps 49, 50, and 51 are controlled by operating circuits extending from the segments I—I of distributor dials 31 and 32 to segments g—g of dial switches 21, 22. Similar circuits may extend from the segments I—I to each of the pairs of segments g—g to i—i, controlling three groups of lamps successively as the brush arms z—z of dials 2, 22 revolve. At the end of one revolution of the brush arms of dial switches 21 and 22, the brush arms z of distributors 31 and 32 will advance to segments II—II. From these segments three other pairs of operating circuits, controlling three other groups of indicating lamps, may extend to the segments g—g to i—i of distributor dials 21 and 22. Three other groups of indicating lamps may be controlled by circuits terminating on the segments III, III of distributor dials 31 and 32, so that we may have in all three times three or nine groups of indicating lamps controlled by the line circuit 8 successively as the distributor brush arms revolve. If nine substitution loop circuits are successively connected in the line, each group of the nine groups of indicating lamps will indicate the condition of the corresponding substitution loop circuit when last connected, thereby indicating the position of the corresponding operating unit which controls that loop circuit. In the case of operating units having only two positions, such as track relays, the high resistance connection at the loop circuit may be omitted, together with relay 46 and indicating lamps 50 and 51. The two required indications will then be produced by open and closed conditions of relay 47, resulting in dark and light indications successively.

Instead of receiving reports to indicate the position of operating units at the substations, it may be desired to transmit control signals or symbols to change the position of one or more control units. The manual switches 34, 35, 48, and 58 will then be thrown to the right. Switches 34 and 35 will open the control circuits for all indicating lamps. Switch 55 will be instrumental in transmitting a symbol to render the desired substations receptive to control symbols as described hereafter, and switch 46 will connect the line 8 through segment af of distributor dial 23 to the brush arm z of distributor 33. At the instant illustrated, line 9 will be connected through segment of the dial 23 and segment I of dial 33 to the brush arm of distributor dial 24 and thence over segment y to the upper blade of three-position control switch 53. When the brush arm of distributor dial 24 advances to segment h, the circuit will be transferred to the lower blade of control switch 53. Thus in the two successive time channels in which the brush 21 of dial 24 makes contact at g and h, respectively, the control line is connected first to the upper and then to the lower blade of the manual switch 55. According to the position of the latter, it is connected to the positive or negative pole of battery 54 or to neither in the following order:

- Upper position: Neither—negative
- Middle position: Negative—positive
- Lower position: Positive—positive

As described hereafter, receiving elements at a substation are arranged to respond selectively to these three combinations of current during two time channels, establishing a distinctive roadside signal or semaphore indication in response to each combination.

Similarly, segment i of dial 24 may be connected through manual switch 55 to the positive or negative pole of battery 54, and transmits a positive or negative current impulse over the control line to select one of two possible operations of another controlled unit at a substation. Similar branch circuits, including other control switches, may extend from segments g, h, and i of dials 25 and 26. During three successive revolutions, as the dials 24, 25, and 26 are connected successively to the line through dial 33, nine control channels will be established. One two-position operating unit, such as a track switch, may be controlled over any one of these channels; any three-position unit, such as a group of roadside signals, requires to be controlled over two such channels.

All of the connections thus far described have involved only segments g, h, and i of dials 21 to 26. During the passage of the brush arms over these segments, the line may be connected, according to the position of manual switch 46, to the relays 41 and 42 for receiving reports, symbols, or through dials 24, 25, and 26 to the control (such as 53, 55) switches for transmitting control symbols. During the contact period at segments a to f, the line is connected to dial 33 irrespective of the position of manual switch 40, and through one of dials 33 to dial 24, 25, or 26.

The first segments a are preferably separated from the last segments i by an angle slightly greater than that between other segments. Seg-
ments a of dials 24, 25, and 26 are permanently connected to positive battery and serves to start all substation distributor dials simultaneously for each revolution as described hereafter.

At each of the dials 24 to 26, two of the three segments b, c, and d are connected to positive or negative battery. The combination of positive, negative and dead segments at each dial is peculiar to that dial only and constitutes a call.

Thus code for one substation which is arranged to respond only to signals transmitted by that particular dial. While I have shown only three dials, 24, 25, and 26, each arranged to call one substation, it should be noted that additional dials, with corresponding segments on the dials 31 to 33, may be provided for any required number of substations. The three segments b, c, and d assigned for calling codes will suffice for twelve distinct codes, viz: codes involving three choices of one dead channel and four combinations of polarity on the remaining two segments. To utilize fully these twelve possible codes (since three-contact distributor 33 can divide line time between only three code sending dials like 24, 25, 26), a twelve-contact distributor must replace 33 and nine more dials like 24, 25, 26 must be added, but each having its b, c, d contacts differently connected. Distributors 31 and 32 also need twelve contacts each, to provide for enough sets of indicating lamps for twelve substations. If the three calling code segments b, c, d are increased to four, there will be six choices of two dead segments, or twenty-four distinct codes in all. If the number of control and report segments on dials 24, 25, etc., be increased from three (viz: g, h, i) to nine, each calling code may establish communication with a group of three substations instead of one. Thus, by increasing the total segments on each dial 24, 25, etc., from nine to sixteen, and by adding the necessary dials and terminal equipment at the central station, the system is adapted to control seventy-two substations instead of three.

If it is desired to transmit one or more control symbols immediately, without awaiting the moment in the automatic cycle when the controlled unit in question would be connected to its manual control, the shaft 28 carrying the distributor dials 31 to 33 may be advanced manually to the position corresponding to the unit to be controlled and held there during one revolution of the shaft 28. The dial selected by the master dial 23 will transmit the calling code for the desired substation and establish the necessary local channels for exchanging report or control symbols.

The segments d of dials 24–26 are connected through manual selector switch 56 either to the negative pole of the battery 54, as shown, or to the positive pole. The former connection constitutes a symbol to establish reporting loop circuits at the substations called, and thereby to control indicating lamps such as 49, 50, and 51 at the central station. The latter connection, always accompanied by the right-hand position of manual switch 40, (since 40 and 56 are mechanically interlocked) establishes connections at the central station and the called substations for transmitting and receiving control symbols to operate controlled units. The segments e are permanently connected to an alternator 12.

Their function is to bring all distributors in the substations into step with switches 21 to 26 at central, irrespective of their previous position, as described hereafter. They also correct any small variation from synchronism which may have occurred since the previous connection by segment a. This latter function is unnecessary with nine segments per distributor as drawn for the sake of clearness, but desirable if a large number of segments is used.

It will be observed that the resistor 45 connected to the polar relay coil 43 corresponds in part with the artificial line or balancing network employed in certain duplex telegraph systems, but differs in that it is not required to balance the line characteristics but merely to produce an effect less than that of the normal line impedance and greater than the line impedance when the latter has been increased to several times its normal value. For this reason a plain resistance as shown, traversed by a constant current, will ordinarily suffice. However, in cases where exceptional line constants make it desirable, the resistor 45 may be replaced by any well-known type of artificial line, as indicated at 45 in Fig. 7. The battery current may then be cut off after each step and reapplied simultaneously during each channel, g, h, i, both to the physical line 9 and the artificial line 45, by a dial switch 15 revolving in step with dials 21 and 22 of Fig. 6. This means for simultaneous application of battery to both lines provides for quick balance (high speed and short channels) even in cases where the line constants of inductance and/or capacitance are unusually high.

Fig. 8 shows means provided to insure that a substation distributor 61 will get in step with the switches 21 to 24 of Fig. 6, even if thrown out of step. 62 is the shaft which carries a single tooth ratchet 62 and the brush arm of distributor 61. It is driven at approximately constant speed; for example, by a motor and governor similar to 58 and 66 in Fig. 2, but through a friction coupling (not shown, but see Fig. 2), which permits the shaft 60 to be stopped by the ratchet 62 without stoppage of the motor. The speed is so adjusted that the brush arm traverses the segments e to f and f to i, substantially in step with dial 21 to 24 (Fig. 6). The spaces e to f and f to i are shorter than the corresponding spaces on dial switches 21 to 24.

Thus distributor 61 will always make contact at segments f and a somewhat before the corresponding contacts are closed at switch 23. A spring biased pawl 76 is located to stop the ratchet 62 at the instant when distributor 61 connects the line to segment e. A magnet 77 is provided to release the pawl 76 and is connected through a condenser 111 to the secondary of transformer 114, the circuit being tuned to respond selectively to the frequency of the alternator 113 (Fig. 6). A moment after distributor 61 has stopped with its brush arm connecting the control line to segment e, dial switch 23 at the central station will connect alternator 113 through its segment e to the line. Alternating current passing over the line and through segment e of distributor 61 will traverse the primary winding of transformer 114 and thence flow over the continuation of control line 9 to the next substation, and ultimately to ground at the end of the line. Current thereby induced in the secondary of transformer 114 will cause the magnet 77 to release the pawl 76, permitting ratchet 62 and distributor 61 to start in step with switches 21 to 26.

Even if distributor 61 is entirely out of step, as for example, when the system is first started in operation with the distributors in random positions, it will revolve to segment e at some time.
within its first revolution. There it will be held by the pawl 76 until it is released by current to which the magnet 77 is responsive. This can occur only when switch 26 connects the line over segment e to the alternator 113, since current of the required character is supplied at no other segment. Hence, even under the condition assumed, distributor 61 will start its second revolution in step with switches 21 to 26.

When the distributor 61 has advanced until its brush arm makes contact at segment a, it will be stopped again by engagement of the ratchet 62 with the pawl 65, adapted to be released by current through the magnet 69. A moment later dial switch 24 at central will connect the line through its segment a to positive battery. Current will then flow over the control line and through segment a of distributor 61, through coils 115 and 116 and magnet 69 to the continuation control line 9, and so through succeeding substations to ground at the end of the line. The magnet 69 being thereby energized will release the pawl 65 and permit the distributor 61 to start again in step with distributors 21 to 26. The coils 115 and 116 are for a purpose described hereafter.

The second starting pawl 65 just described serves to correct any variation from synchronism which may have occurred during approximately one-half revolution, but is not capable of bringing the commutator into step from a random position as may be done by the pawl 76, for the reason that it is responsive to direct current received through segment a of distributor 61, whether the current originated at segment a of switch 24 or at any other segment.

As previously described, the segments b, c, and d of switches 24-26 (Fig. 6), are used to transmit over the line during each revolution a distinctive symbol calling only such substations as are required to respond during that revolution of switches 21 to 26, the symbol consisting of positive or negative current on two of the three channels b, c, and d; and the segment f, together with manual switch 56, serves to transmit positive current over the line when control symbols are to be transmitted from the central station and negative current when report symbols are to be transmitted from the substation.

Fig. 9 shows the means provided at the substation for giving effect to these calling and selecting symbols. At 61 is shown a portion of the distributor 61 of Fig. 8. At the starting segment a positive current is supplied by the central station passes through the line 9, through coils 115 and 116, and the starting coil 69 (see Fig. 8 also) through the outgoing portion of line 9 to substations beyond and ultimately to ground at the end of the line. The coils 115 and 116 are operating coils of two polar relays biased to maintain their last operated position and are connected in each case to move the contact to its open position so that the relays are opened at the start of each revolution of the distributor.

115 and 116 are additional operating coils on the same relays, connected, respectively, (in the case shown) to segments b and c of the distributor and to the outgoing section of the line 9. It will be recalled that channels b, c, and d are reserved for the (twelve possible) calling codes of the system shown. Incidentally, the code or symbol necessary to call the one substation shown in Fig. 9 is not one of those sent by dials 24, 25, 26, as shown in Fig. 6. Since the relays are opened at the start of each revolution, i.e., during channel 8, they can both be closed only when the channels b and c have been energized during a given revolution by current of the particular polarities required to close the contacts 120 and 121. In other words, both contacts will be closed only during that particular revolution when the calling symbol which includes these two channels and the polarity combination is transmitted from the central station.

When closed, during one particular revolution, the contacts 120 and 121 establish and maintain during that revolution only a local circuit from grounded battery 19, to a polar relay contact 123 controlled by a coil 122 which is connected in series with the control line 9, making the channel established by the segments f of dial switches 24 and 61. If positive current is received during this channel, contact finger 123 will swing the left as shown, completing the local circuit through neutral relay coil 126, which sets up loop circuits for characteristically affecting report symbols during the next few channels.

Fig. 10 shows segments g to i of distributor 61 and loop circuits placed in series with the control line 9 through these segments during successive operating stages of the distributor, either to receive control symbols or characteristically to affect report symbols, viz: from segment i through polar relay coil 126 or through report switch 132 to the outgoing portion of line 9; from segment h through polar relay coil 128 or report switch 133 to the same point; and from segment g through polar relay coil 130 or report switch 135 to the same point. The relay coils 126, 128, and 130 are bridged by back contacts of relay 124, which is shown energized in Fig. 9. The back contacts are therefore open and current through the loop circuits must traverse the coils. Report switches 132, 133, and 135 are bridged by back contacts of relay 125 which is shown de-energized in Fig. 9. The report switches are therefore circuited and ineffective. Line current through the channels g, h, and i respectively, traverses the relay coils 130, 128, and 126 and determines the positions which their respective contact fingers 131, 129, and 127 will assume, and which (by virtue of inherent bias toward their operated positions) they will maintain until reversed by opposite current in their operating coils. Thus the position of the contact fingers 131, 129, and 127 is determined by the polarity of line current through the corresponding channels g, h, i, in that revolution of dial 61 after relay 124 has been energized as described by the calling symbol for this substation. The coils 126, 128, and 130 are connected to close their respective contact fingers downward when the current through them is positive, upward when negative. As shown, the finger 127 has last been actuated by positive current and is down, connecting the local battery 19 to the "reverse" operating circuit 138 for the track switch. Had positive current been received in channel i, finger 127 would have been up energizing the "normal" track switch operating circuit 137.

Operating coil 128, as shown, has last received negative current over the lower blade of control switch 53 (Fig. 6) and channel h, and its contact finger 129 is therefore up, energizing local control wire 139 to set up roadside signals for east
bound traffic. This occurs irrespective of the position of finger 131; but when finger 129 is closed downward by positive current in its operating coil, it establishes a circuit to the earth-bound wire and connects the battery 19 to contact finger 131. The up or down position of the latter, according as positive or negative current flowed through coil 130 during channel 9 determines whether battery will now go on local wire 141 that sets the roadside signals for inbound traffic; or on local wire 140 that sets them to "stop".

Response to control symbols over channels 9, 10, and 11, as just described, was dependent upon the previous receipt of positive current through manual switch 55 (Fig. 6) and channel 9, causing contact finger 123 (Fig. 9) to close at the left and energize relay 124. When the manual switch 56 is closed to the left, as shown in Fig. 6, negative current will flow in channel 9, and contact finger 123 will close at the right and energize relay 125. The relay coils 123 and 125 will then be short-circuited by contacts of the deenergized relay 124 and therefore rendered ineffective; but the contacts of relay 125 will be open and the impulses sent down the line. Channels 9, 10, and 11 are reversed when finger 29 is closed downward by "central." This impulse on a also restores to normal or open contact condition (wiping out the influence of past conditions), the two code receiving polar relays at all substations, (120 and 121, Fig. 9). It is by the twelve possible combinations of polarities in each of these two relays with their connections to the three time channels b, c, d, that each substation is differentiated from the others and is adapted to answer just one of the twelve symbols or codes.

Positive and/or negative impulses on channels b, c, d, constitute the substation selecting symbols or codes. Each one of these (twelve possible) is determined by the positive or negative battery conditions on two out of the a, b, c, segments of dials 24, 25, etc.

Alternating current on channel e puts all substations in synchronism with central, even if locally displaced.

Positive or negative goes out on channel f, according to the right or left position of manual switch 56, and this choice determines whether the impulses to be sent on channels g, h, i, shall cause movement of roadside signals, track switches, or the like, or shall light indicating lamps at central to report conditions of the track switch, track relay, semaphore or the like.

Channels g, h, i, when manual switch 56 is in the right-hand or "control" position, carry the codes that actually determine the motion of roadside signals at the selected substation. As illustrated, only three codes are sent on g, h, i, (eight are possible, using either of two polarities or either or both of two channels). More are needed to control roadside conditions and complicate substation receiving arrangements.

Channel i, with manual switch 56 in right-hand control position, carries a two-unit code (positive or negative) to set the track switch to normal or reverse.

Channels g, h, i, when manual switch 56 is in left-hand or "report" position, carry no codes but are used as mere individual channels for connecting a battery at "central" to individual substation loops, each associated with a track switch, a roadside signal, or a track relay, during which connections these three loop impedances are compared, individually, to an artificial load at central and their conditions individually recorded at central on lamps.

Fig. 11 shows a modified system in which positive and negative direct current impulses during three time channels transmit the necessary symbols to control the operating units at one substation, and in which alternating currents superimposed on the direct current during the same time channels transmit the necessary report symbols to indicate at the central station the existing positions of the operating units. As in Figs. 6 to 10, the central station automatically transmits a program of several cycles, each of which includes a calling signal for one or more substations, followed by the necessary channels for control and report symbols at the called substations; and provision is made for manually adjusting.
vancing the program to any particular cycle if immediate communication with the corresponding substations is desired. The calling code in each cycle consists in current flow during three among seven channels assigned for this purpose; and completion of the appropriate calling code automatically starts the receiver at the called substations in step with the central station transmitter.

In some applications of this invention, the control line will extend for many miles and have a resistance of a thousand ohms or more. Certain magnet windings at all substations are required to function simultaneously. If all of these windings were connected to the line in multiple, the required resistance of each winding for efficient operation would be much higher than is readily attainable. Therefore, all substation windings are shown connected serially in the line, under which condition the most efficient resistance values are easily attainable. On the other hand, contact devices are required in certain substation circuits which function one at a time to transmit report symbols. These circuits are shown as branches from the line to ground in order to keep the line clear of the large number of contacts in series which it would otherwise include.

We have chosen to illustrate a substation receiver and transmitter which is coupled to the line only by the branch circuits for report symbols already mentioned and by two magnets which serve to translate line impulses into mechanical movements. All necessary functions of interpretation and selection are accomplished mechanically by these movements. However, it will be readily understood that the same functions could be accomplished by a dial switch and a group of relays similar to those shown in Figs. 8 to 10.

21, 22, and 23 in Fig. 11 are three dial switches at the central station, driven at uniform speed by a common shaft 20. 21 is a three-point dial switch arranged to connect the brush arms of dials 21, 22 and 23 successively to the control line 8. It is advanced one step automatically at the end of each revolution of dials 21 to 23 by cam 27, follower 26 and pawl 29 acting on ratchet wheel 27, as shown in Fig. 11a; but a slip coupling in its driving permits of manual setting by knob K to connect either dial to the line when desired. Each of the dials 21 to 23 has eighteen segments lettered from a to r. The segments shown as white circles are always energized with either positive or negative potential, whereas the black circles represent segments which are always dead. On each dial, nine segments a to f, transmit a calling signal for the substations associated with that dial. Segments a and f are dead on all dials, and serve to mark the start and finish of the calling signal.

Of the seven intervening segments, a distinctive combination of three segments is connected to positive battery and constitutes the selective calling symbol for the associated substations. Three dials are shown, distinguished by three call combinations, and the resulting magnetic potential of each dial; but thirty-five combinations of three segments among seven are available, so that the seven calling segments will suffice for any number of dials up to thirty-five.

Each of the segments j to r is energized through a transmitting and receiving channel as described hereafter, but the connections are indicated only for segment r of dial 21.

As the brush arms of dials 21 to 23 connect control line 3 to each live segment in turn, direct current flows from battery 54 over the control line to condenser 157 at the first substation. Since it is blocked by the shunt path through the coils of polar magnet 163 and neutral magnet 69. In the same manner it traverses the magnet coils of each substation in turn and finally goes to ground through a network 155—158 at the end of the cycle and returns through the earth to through alternators 142 and 143 to the center of battery 54. During certain time channels polar magnet 163 selects local operating circuits in response to control symbols received over the line. Neutral magnet 69 and associated parts respond selectively to calling codes transmitted during channels a to f by the central station dial switches, and start sending and receiving elements for report and control signals only through those cycles which include the distinctive calling code for this substation. Magnet 68 releases with a slight time lag sufficient to bridge the interval between two successive live channels, even when they are of opposite polarity, but must release positively when current is interrupted for the duration of one time channel. If necessary mechanical and electromagnetic inertia will not produce the required time lag, the electromagnetic inertia may be increased by well-known means such as a short-circuited path surrounding a portion of the pole face.

158 is a short-circuited by local energy at slightly more than two revolutions per revolution of central station dials 21 to 23, and hence completing one revolution in slightly less than nine time channels. 156, 151, and 162 are a group of wheels rigidly coupled one to another and frictionally coupled to shaft 156, upon which they are mounted. 164, 165, 166, and 167 are four pawls attached to a common rock shaft 168 and jointly actuated by neutral magnet 69. When the latter is energized, pawl 164 engages the single tooth of wheel 165, and when it is deenergized, pawl 165 engages the three intermittent teeth of wheel 161. During nine successive channels j to r in each cycle transmitted from the central station, magnet 59 will be energized. Irrespective of its previous position, wheel 160 will be stopped at some time during this period, and will be released at the first dead cycle, 160, of the network a. Thereafter its progress will depend upon wheel 161. If live channels occur coincidently with the points of engagement for the three teeth of this wheel, the three wheels 160, 161, and 162 will advance without interruption until stopped again by pawl 164 at live channel j. For teeth as drawn, this condition will obtain during the cycle transmitted by dial 21, in which b, c, and d are live channels. In this case the projection on wheel 162 will lift follower 169 during channel t and thereby release the earth calling code than bcd is received, wheel 161 will be delayed at one or more of its three teeth, and cam wheel 162 will release pawl 170 during one of the live channels j to t.

171 is a sleeve mounted upon shaft 156 and frictionally driven thereby. Upon it are rigidly mounted three threaded wheels 172, 173 and 174, a brush arm of dial switch 61, and a cam 175. Wheels 172 and 173, respectively, are engaged by paws 166 and 167, actuated by magnet 69. Wheel 174 is engaged by pawl 168. After any group of nine live channels j to r these wheels will occupy the position shown with wheels 172 75.
and 174 engaged by their respective pawls, and can be released only when both pawls are released simultaneously. Pawl 166 is released only during dead channels, and pawl 170 at a time and in a position such that if released, the machine i during cycles in which the distinctive

calling code for this substation is received, and one of the live channels to to during all other cycles. In the former case, pawls 166 and 170 will be released simultaneously and sleeve 171 will be allowed to start. In the latter case, the sleeve will remain locked by pawl 166 at the time it is released by pawl 170. In other words, the sleeve will start if the distinctive call for this station has been received, and not otherwise. At other substations having other tooth arrangements on the wheels 161, sleeve 171 will start responsively to other calling codes.

As in the cycle transmitted by dial 21, the dead channel i may be preceded by other dead channels. In this case pawl 165 will have been previously released when pawl 170 is released by the appropriate calling code. The starting time for sleeve 171 will depend solely upon wheel 162, and ultimately upon the speed of shaft 156, after the release of wheel 158 eight time channels earlier. In order to correct the slight gain of shaft 156 during this time with respect to the time channels of the impulses, pawl 167 is arranged to engage wheel 167 and stop it at a position corresponding to time channel i and release it accurately in step with that time channel.

For clearness of diagrammatic representation, we have shown wheels 156, 158, and 162 and wheels 172, 173, and 174 with progressively increasing diameter; but in practice we prefer to make all these wheels of equal diameter.

When released as described, sleeve 171 advances for one revolution in substantial synchronism with the time channels of line current. During this revolution dial switch 61 establishes three local channels p, q, and r, for report symbols; and cam 175 acting through follower 176 and rock shaft 177 releases pawl 176 and thereby engages one mechanical channel, viz: channel r, for receiving a control symbol.

183 is a second sleeve loosely mounted upon shaft 156. Attached to this sleeve there are three wheels 179, 180, and 181, and a triple contact brush 184. This assemblage is driven by a spring 187 attached to a hub 182 which is frictionally driven by the shaft, so that the spring is always wound and ready to advance sleeve 186 rapidly whenever the latter is not restrained.

Wheel 181 is normally held at one of six positions by the pawl 178 until the latter is released, as already described, at channel r. If the current released by polar magnet 163 during this time channel is positive, pawls 183 and 184 will retain the positions in which they are shown, with the former still locking wheel 179. No movement of sleeve 186 will occur, and the triple brush 189 will continue to contact with its upper segment, and maintain a circuit from battery 19 to local operating wire 127, which may be the normal operating wire for a track switch or some other operating unit. On the other hand, if current through the polar magnet 163 is negative during time channel r, the position of pawls 182 and 184 will reverse. Sleeve 185 will advance 90° and come to rest with pawl 184 engaging wheel 180, and the battery connected through brush 189 to the lower contact segment, supplying current to wire 186. This wire may operate the track switch to its reverse position. In either case pawl 186 will again engage wheel 181 before the succeeding time channel, and will thereby maintain the status quo until the next recurrence of channel r in a cycle which includes the calling code for this substation. Other units similar to sleeve 186 and the associated parts may be provided for other channels such as p and q, and may be jointly controlled by the same magnetic field. It will be readily recognized that the contact brush 189 with its controlling elements is functionally equivalent to a polarized relay and a dial switch segment, since it selects and holds one of the contacts in accordance with the polarity of line current during a particular time channel.

The mechanical contacts described have certain advantages in that several contacts may be controlled during successive time channels by the same magnet, and in that contact movement and pressure are derived from local energy and are not limited by the energy which can be transmitted over the control line. Hence, we prefer to design the contacts with sufficient capacity to control the local operating circuits directly without intervention of secondary relays or contactors.

The upper portion of Fig. 11 shows the local circuits at the central station of which current is supplied to one signaling channel r. It will be understood that similar circuits extend from each of segments j to r on each of the dials 21 to 23 to the positive and negative terminals of battery 54; but the battery and two alternators 142 and 143 are common to all of the channels. Each signaling segment is connected to the middle fixed contact of a corresponding control switch 55.

The right and left fixed contacts, respectively, are connected to the negative and positive poles of battery 54, while the center of the battery is connected through alternators 142 and 143 to ground.

For each segment and its associated control switch there is a network as shown connected between the blades of the control switch. When the latter is thrown to the left, positive current flows from positive battery to the left switch blade, and thence from left to right through the network to the right-hand switch blade, whence it flows over the dial switch segment to the line. This may be regarded as the positive direct current in the line, constituting one of the two direct current symbols which may be transmitted over the line. The other symbol, viz: negative current is transmitted when the control switch 55 is thrown to the right. Current then flows outward from the center of the battery 55 through alternators 143 and 142 to ground, and the return current reaching the central station over the control line 9 passes through a dial switch segment (which, for the channel illustrated will be segment r), to the left-hand blade of control switch 55, and thence from left to right through the network to the right-hand switch blade and the negative pole of battery 54. It should be observed that reversal of control switch 55 reverses the direction of current flow in the control line 9, but does not change the direction of flow through the network which is from left to right in either case. Thus the control switch determines the polarity of current in control line 9 during time channel r and thereby determines the local control circuit 157 or 158 which will be selected by contact device 185 at a certain substation; but it does not affect the network, which comprises the receiving elements for report symbols over channel r.
The network includes three branch paths from left to right, joined at their midpoints by a tie conductor 156. The first path includes coils 143 and 147 and reactors 145 and 146; the second path, condensers 150 and 151; and the third path, coils 152 and 155 and rectifiers 153 and 154. Of these paths only the first is conductive for battery current, the second being blocked by condensers and the third by rectifiers opposed to battery current. Current flowing from left to right. 148 is a polar relay contact responsive jointly to the coils 144 and 152, and 149 is a polar relay contact responsive jointly to the coils 147 and 155. These contacts may control indicating lamp circuits similar to those shown in Fig. 6 for the relays 45 and 47. When actuated by battery current flowing through the upper coils only as described, both contacts move to the left as shown.

Superposed upon the battery potential are 500 and 750 cycle alternating potentials induced by the alternators 142 and 143, respectively. The resulting alternating components of current in the line are dependent upon the impedance of the connected branch. As already mentioned, the magnet coils at each substation are bridged by a condenser 157 offering little impedance to alternating current of either frequency, so that the line impedance at any given substation is kept as small as possible. The ground connection for direct current at the end of the line is made through a network consisting of two meshes 158 and 159. These two meshes are tuned substantially to prevent the passage of 500 and 750 cycle currents, respectively. Hence the alternating current in the line is substantially limited to that which can flow through a branch circuit at some substation. During time channel r, such a branch may be established at one substation through dial switch 61 and report switch 132. The latter may be actuated by the track switch, which is controlled during the same time channel by control wires 137 and 138. The centre position (as shown) of the report switch may indicate that the track switch is unlocked, and may open the branch circuit. In this case no appreciable alternating current will flow into the line during time channel r. If the track switch is locked in its normal position, the report switch may establish a branch path to ground through a circuit 161', tuned to offer little impedance to 500-cycle current, but high impedance to 750-cycle current. A substantial 500-cycle component of current will then flow into the line during time channel r. When the track switch is locked at its reverse position, report switch 133 may establish a path 162', tuned to pass a substantial 750-cycle component, but no material 500-cycle current. Thus, according as the track switch is normal, reversed or unlocked, there will flow into the line during channel r a substantial 500-cycle component, a substantial 750-cycle component, or neither. It should be noted that the branch circuits 161' and 162' are blocked for direct current by condensers included in both circuits.

The mesh 156, 150, 144, 145 of the receiving network is tuned to offer very high impedance to 500-cycle current, but low impedance to 750-cycle current. Accordingly, a substantial 500-cycle current flowing into the line will cause a large drop of potential in this mesh, which will be impressed upon the branch path comprising tie 156, rectifier 153 and coil 152. The coil 152, the voltage induced by 500-cycle alternator 142, and the circuit constants are so chosen that, under this condition, coil 152 will overbalance coil 144 and cause the contact 149 to reverse. In like manner, the mesh 156, 151, 147, and 146 is tuned to oppose the flow of 750-cycle current and thereby cause the coil to reverse the contact 149 when a substantial current of this frequency flows into the line. Thus, either one of the contacts 148 and 149, or neither, may reverse during the contact period at any time according as the substantial current of 500 cycles or 750 cycles or neither flows into the line; and hence, according as the track switch is normal, reversed or unlocked.

As described, a single channel r is capable of transmitting simultaneously the necessary control symbol to govern the operation of a track switch and the necessary report symbol to indicate its actual position. In like manner, two channels may govern a group of signals operating in three positions; and one of these channels may indicate at the central station the position of either of these channels. The other channel may indicate the position of a track relay. Thus, three time channels, p, q, and r, suffice for transmitting the necessary control and report signals for one typical substation as shown in Fig. 1. In the same manner, channels j, k, and l, and channels m, n, and o, of cycle 21, may be used for communication with two other substation, or control and report symbols may be exchanged with three substation in all during one revolution of either dial at the central station. If the dials are adjusted to complete one revolution in 0.4 second, control symbols may be sent and report symbols received from any given substation within this 35 interval by manually setting dial switch 31 to the desired cycle. Since the control and report symbols are simultaneous, the latter will indicate the initial position of the operated units, not the position they may assume in response to the control symbols. Completion of the desired operation will be reported during the first recurrence of the same cycle after the actual completion of the operation. If desired, dial switch 31 may be held stationary, causing repetitions of the same cycle until completion of the operation has been reported. In this case, the report will be received within four-tenths second after actual completion of the operation. If the automatic program is determined by dial 31 is not interrupted, communication both ways will be established at intervals, depending upon the number of cycles included in the program. For example, thirty-five cycles would provide for 105 substation. At a speed of one cycle per 0.4 second, the positions of operating units at each substation would be reported every 14 seconds. Control symbols, as determined by the positions of control switches such as 55, would be reaffirmed substantially at intervals, but would change the local control circuits at the any indication of control action only when the positions of control switches had been changed. In effect, the operating units will be continuously responsive to the position of the control switches with a possible time lag of 14 seconds, while the central station will respond to the central station with a like time lag.
of control symbols only, and provision may be made for manual interruption of the one class of signals and substitution of the other class. Furthermore, the particular choice of symbols we have described is largely arbitrary. We have described for substitution calls a code of positive and dead channels; for control symbols, positive and negative direct current channels; and for report symbols, 500-cycle and 750-cycle alternating current or neither. But this same current could equally well be distributed in other ways among the same functions. For example, if the polar magnet 163 and the neutral magnet 69 are interchanged, and the former biased to take its positive position when deenergized, calling signals may be given by negative and zero or negative and positive currents, and control signals may be given by positive and zero currents. Or with suitable modifications of the pawls and of the symbols transmitted by the central station, polar magnet 163 may be replaced by a neutral magnet shunted by a rectifier to render it unresponsive to current of one polarity and magnet 69 may be shunted by a rectifier to render it unresponsive to current of the opposite polarity. The only essential limitation on the assignment of symbols for calling, control signals, and report symbols, is that wheels 160 and 172 shall engage their pawls throughout the group of time channels assigned for control and report symbols, and wheels 161 and 173 shall engage their pawls at certain other times as required for response to calling signals. In the code described, zero current is a symbol reserved exclusively for calling signals, but any other one symbol may be reserved for the same purpose.

The specific cycle described in which nine channels are assigned for call signals and nine for control and report signals, is advantageous in that it permits control of a large number of substation without involving synchronism over a longer period than nine time channels from any given start; but many other assignments of channels are obviously possible, for example, eight time channels for calls and twelve, or three substation groups, for control. This combination permits distinctive calls for twenty groups of four substation, eighty substation in all. The number of channels may be less than the number of control channels, but should not be less, because the receiving device for calls must reach its starting point from any position within the period assigned to control signals.

Fig. 12 shows a modification of Fig. 11 in which polar magnet winding 162 is replaced by two opposed windings 163 and 163a, and neutral magnet winding 69 is replaced by two windings 69 and 69a. The windings 163 and 69a are energized by pulsating current derived from transformer winding 191 and controlled by an electric discharge relay or valve 192. Windings 163 and 69 are energized by transformer winding 193, subject to control by a discharge relay or valve 194. 193 is a primary winding inducing potential in both secondary windings 191 and 163a. 193 is a source of the so-called shunt current which comprises a pair of slip rings connected to the armature of a high speed direct current motor connected through reduction gearing to operate receiver shaft 195 (Fig. 11).

The valves 192 and 194 are of a relay type such as the so-called Thyatron. They are characterized by the fact that current starts in the plate circuit only when the grid potential, with respect to the filament, is above a certain critical value, but that plate current once started will persist irrespective of grid potential until the succeeding zero point of the plate current wave. Alternating potential as described is applied to the plate circuit in order that such zero point should recur at frequent intervals; and in order that the times of current start and interruption may approximately coincide with the make and break times at the central station dial switches, the frequency impressed on the plate circuits should be relatively high, insuring several positive half waves during each time channel. A bias battery 197 is included in the grid connection of each valve and adjusted to prevent the flow of plate current during dead channels with the line at ground potential. Each valve is further provided with a filament battery 198.

The filament of valve 192 is grounded and its grid is connected to control line 9. When the potential of the latter is positive, current will flow through the plate circuit and through magnet coils 162 and 69, producing the same effects as positive line current through the corresponding coils in Fig. 11.

The grid circuit of valve 194 is grounded, and the filament is connected to the control line. When the line is negative with respect to ground the grid becomes relatively positive. Current flows through the plate circuit and through coils 163a and 69a, producing the same effects as negative line current in the corresponding coils of Fig. 11.

In order that positive or negative peaks in the alternating components of line potential may not cause current to flow through the plate circuits of the valves, the potentials of central station battery 64, bias batteries 197, and alternators 142 and 143 must be so coordinated that the grid potential of one valve or the other will be below the critical value required to start plate current throughout the pulsations of the resultant line potential.

It is to be observed that the filament to grid circuits of the valves 192 and 194 constitute branch circuits from the line to ground, and that two such branches are always connected to the line at each substation. It was previously stated that the high resistance of the line and the limits of resistance for which coils can conveniently be wound made this type of multiple circuit undesirable for coils connected directly to the line. Owing to the exceedingly high resistance of the grid circuits in the valves, the same objection does not obtain in Fig. 12. Since the grid circuits are controlled by line potential rather than line current, the ground connection through network 159-159 at the end of the line is unnecessary in the present case.

In Fig. 13, we show another modification in which all control signals required for one substation are embodied within a group of seven time channels, each individual signal comprising two live channels and five dead channels. The codes are so arranged that they may overlap without conflict; for example, if channels 1 to 7 are assigned to substation 2, channels 2 to 8 may be assigned to substation 3 by six channels from 2 to 9 to substation 4; but no substation will respond to signals transmitted for any other of the substations which have certain channels in common. A cycle of N time channels provides codes for N substations; but the last code overlaps the beginning of the cycle by an even number. Any control symbol may be initiated at any time and will be completed whenever the necessary
time channels become available thereafter. If
initiated coincidently with the first of the re-
quired time channels, the signal will be com-
pleted within a space of seven time channels.
If
initiated at the most unfavorable point in the
cycle it will be completed within a space of N
plus 6 time channels.

Control signals are transmitted exclusively by
negative current impulses. At all times when
such signals are not being transmitted, a pro-
gram of positive impulses is automatically transmitted,
and report signals are thereby received from each
operating unit of every substation in rotation.

The report program occupies three time chan-
nels per substation, and when the line is not in
use for control signals, reports are received from
all operating units within a period of 3N time
channels, or the equivalent of three control signal
cycles.

In Fig. 13, parts 20 to 52 are receiving elements
at the central station for report signals.
They are identical with the corresponding parts in Fig.
6, save only that in Fig. 13 the dials 21 and 22
have segments for each time cycle of the whole
program and select directly the relays 46 and 47
for retaining report indications, whereas in Fig.
6 the corresponding selection was effected jointly
by dials 21 and 22 and dials 31 and 32. As drawn,
each of the dials 21 and 22 has forty-eight seg-
ments, sufficient for sixteen groups of three seg-
ments per substation. It is to be understood that
relays 46 and 47 of Fig. 13 may control indicating
lamps as shown in Fig. 6. Thus, in the ab-
sence of manual intervention, dials 21 and 22 will
maintain a continuous program of 48 time chan-
nels, and during each time channel one group of
indicating lamps may be controlled, showing the
position of one operating unit at a substation.

The indications of each group of lamps will be
brought up-to-date at intervals of 48 time chan-
nels, or about one second if the dials are operated
at a speed of fifty channels per second.

In Fig. 6, switches 34, 35, 46, and 55 were pro-
vided to select receiving circuits for report sig-
nals or sending circuits for control signals.

In Fig. 13 the same function is effected by a drum
controller 203 mounted upon the shaft 20 and
for retaining report indications. As described here-
fore, the two-point ratchet 199 and a pawl 200
normally hold the controller at one of two normal positions in which the
control line 9 is connected to the receiving cir-
cuits and relay coils 46 and 47 are connected to
ground. By depressing a push button shown on
pawl 200 the latter may be released. Ratchet 199
and controller 203 will then advance one-half
revolution with shaft 20. During this time the
line 9 is connected for a period of 22 time chan-
nels or more to the sending circuits instead of the
receiving circuits and the ground connection
from relays 46 and 47 is broken to prevent any
change at the indicating lamps during the time
that their control over line 9 is interrupted.

While the controller 203 is travelling between
one normal or receiving position and the next,
each connected substation. This brush arm is
grounded to shaft 28 and makes three revolutions
for each revolution of the latter, so that con-
tacts are made simultaneously at dial 24 and at
dials 21 and 22; but contact is made at each
segment of dial 24 during three different time
channels as established by dials 21 and 22.

From the segments of dial 24 five connections
lead to each substation panel, such as 13 or 14,
in Fig. 1, terminating on the control switches for
signals and track switch machines. These con-
nections are indicated only for control switches
53 and 55 of substation panel 13 and control
switches 53 and 55 of substation panel 14. The
complete circuits would include five connections
from each segment of the dial switch.

201 and 202 are two dial switches mounted upon
a common shaft and manually operated. Both
brush arms are connected to the negative pole
of battery 54, the positive pole being grounded.

Each segment of dial 201 is connected to the
blade of the control switch 53, 53, etc., on one
substation control panel, and the corresponding
segment on dial 202 is connected to the blade of
control switch 55, 55, etc., on the same panel.

Thus, at a given time, the battery may be con-
nected at will to the control switches of one sub-
station control panel and only one. Connections
from the segments of dial 24 to all other sub-
station control panels are then dead-ended as
can be seen, for example, by tracing connections
from the dial through control switches 53 and
55 on panel 14. Thus the panel selected by dials
201 and 202 has exclusive control of battery con-
nections to dial 24. If preferred, it will be readily
understood that an equivalent group of relays
may be substituted for dial switches 201 and 202,
and that battery connections to any panel may
then be established by pressing a button on the
panel.

When battery connections have been estab-
lished to a given substation panel, control
switches 55 and 53 on that control panel will complete
paths, respectively, to one segment se-
lected among an assigned group of two on dial
24, and to one segment selected among another
group of three. As described earlier, the receiving
relays at the corresponding sub-
stations are so connected that they respond only
when one negative impulse is received during each
of the corresponding groups of two and three
time channels, respectively. If channels of the
respective groups are indicated by capital letters
and small letters, each of the groups for one substa-
tion may be assigned according to one of the following
two arrangements: A'B'C'D', or A'D'B'. In either
case, each choice of one capital and one small
letter is peculiar to a single substation and
cannot be duplicated in any overlapping group sim-
ilarly assigned. Connections shown in Fig. 13 are
connected to the first arrangement. The com-
pound list of channel assignments for sixteen sub-
stations, involving sixteen channels lettered from
a to p, is as follows:

<table>
<thead>
<tr>
<th>Substation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td>G</td>
<td>H</td>
<td>I</td>
<td>J</td>
<td>K</td>
<td>L</td>
<td>M</td>
<td>N</td>
<td>O</td>
<td>P</td>
</tr>
</tbody>
</table>

control line 9 is connected to the brush arm of
dial 24, which has sixteen points, one point for

Among the capital letters it will be noted that
substation 1 includes A in common with substa-
tion 16 and B in common with substation 2; but neither of these two columns includes any of the three small letters, c, e, g. No other column includes A or B. Hence, only substation 1 will respond to a signal involving negative current during channel A or B and during channel c, e, or g. In like manner, each column, i.e., each group of channels assigned for signals to one substation, has no capital in common with each adjoining column, and has no capital in common with any other column. If the overlapping series had been started with the alternate sequence ADefg, similar relations would obtain between adjacent columns.

II. It should be observed that the channels assigned to the last substation overlap the beginning of the cycle as far as the sixth channel. Since each substation group extends over a space of seven channels, this full overlap is not possible if the whole number of substation is less than seven plus six, or thirteen. Consequently, more than one channel per substation will be required if less than thirteen substation are involved.

As described, a continuous program of automatic report signals from battery 190 will normally interrupt to transmit control signals for changing the position of certain operating units. The procedure for the latter purpose is: set control switches 53 and 55 at the station panel which controls the units in question and to correspond with the desired position of the units; turn the dial switches 201 and 202 to the position corresponding to the same panel. Negative potential from the battery is now supplied to the control switches and through them to the segments of dial 24 where they connect to the desired control code.

Press the button of pawl 206, releasing ratchet 199 and controller 203. The latter will disconnect the report circuits and substitute a connection from dial 24 to the line during somewhat more than one revolution of the dial, within which time the code that has been set up on the dial will be transmitted over the line. Thereafter the normal receiving connections for reports will be automatically reestablished.

From the central station report or control impulses are transmitted over control line 9 to all substations. At each substation a branch circuit for report signals passes through a rectifier 204 connected to pass positive current only, and at certain times in the program through dial switch 205, adjustable resistor 206 and dial switch 207 to segment a, b, or c, and thence to report switch 132, 133, or 135. By means described hereafter dial switch 205 revolves in synchronism with dials 21 and 22. Dial switch 207 is geared to dial 205 and completes one revolution in eight time channels, but has segments only for the time channels assigned for report signals at this particular substation. Dial 205 has a single segment located to connect dial 207 to the line during one revolution in which time channels a, b, and c occur. Adjustable resistors 236 at the various substations are set so that the total resistance over the line and the resistor to dial switch 207 is the same for each substation, irrespective of its distance from the central station. For example, at the last substation the resistor may be set for zero resistance, and at a substation directly adjoining the central station it may be set for resistance equal to the line resistance to the last substation.

As in Figs. 6 to 10 report switches 132, 133, and 135 may be controlled respectively by a track relay, a track switch and a group of signals; and during the time channels when they are connected to the line they may indicate at the central station the positions of these units, according to as they establish no path, a high resistance path, or a path of normal line resistance to ground.

At each sub-station another branch circuit is provided for negative control impulses, passing through rectifier 208, which is connected to pass negative current only, and at appropriate times through dial switches 209 and 210 and relay 211, 212, 213, 214, or 215, to ground. Dial switches 209 and 210 respectively are mounted upon the same shafts as dials 205 and 207, revolving, respectively once in a full program of 48 time channels and once in eight time channels. As previously stated the 48 channel program includes three control cycles each of 16 time channels. Hence three segments are provided on dial 209, each of which connects dial 210 to the line during one revolution. Separate dials 209 and 210 are provided to select revolutions in which dials 209 and 210 will be connected to the line because there is no fixed relation between the channels assigned for control signals to a given sub-station and those assigned for report signals from the same sub-station. Certain combinations on a single dial would conflict. For example, in the case illustrated dials 207 and 210 must not both be connected to the line during one revolution while dial 210 only must be connected during two other revolutions in the program of six revolutions.

Each of the relays 211 to 216 has two windings 216 and 217. The five coils 210 in multiple are energized from battery 190 and 218. The latter is mounted upon the shaft of dials 205 and 207, and connects the coils to the battery during the whole of each revolution in which dial 210 is connected to the line, and during about four subsequent time channels. These coils are designed to hold closed any relay operated by the coils 216; but their magnetizing effect is insufficient to operate the relays from their open positions. Thus, any relay once closed will remain closed till the last channel assigned for this sub-station, and during several time channels thereafter.

Each of the five operating coils 216 is connected to the line by dial switches 210 and 219 during one of the five channels a, b, c, e, and g, which are the five channels assigned for control codes to this sub-station. If energy is not received at either of the two channels a or b, the lower finger of relay 219 or 214 will connect battery 19 to bus connection 218. As already stated, this contact will be maintained until time channel g and for several time channels thereafter. During this period if energy is received over channel a, c, e, or g, relay 213, 212, or 211 will also close and connect the energized bus to one of the three control wires 135, 140, or 141 for operating a group of signals to one of three positions. At the same time the upper finger of relay 213, 212, or 211 will connect battery to bus 220 and thence over the upper finger of relay 215 or 214 to control wire 137 or 138 for operating a switch to its normal or reversed position. Thus, the relays as arranged respond to signals of the type which the central station is adapted to, to negative current over one of two channels a or b provided negative current is also transmitted over one of three channels, c, e, or g, and not otherwise.

Since every control symbol must involve one energized channel in the group ab, and one in c, e, or g, the five operating windings on the relay are energized simultaneously; this is accomplished by building the operating and control circuits into the common relay 216, and connecting its two windings in series to the battery 19.
the group ceg, at least one relay for each group must be provided at each sub-station even though (in special cases) no switch or no signal control may be required at a given sub-station. For example, if no signal control were required at this sub-station control switch 55 at the central station could be replaced by a permanent connection to segment c of dial 24. Relays 211 and 212 at the sub-station could be omitted, but relay 213 connected in channel c would still be required to make the response of relays 214 and 215 dependent on one energized channel of the group ceg.

Relays 211 to 215 should preferably be small relays such, for example, as are well known in the telephone art, requiring little time and little energy for operation and adapted to control relatively small currents through their contacts. It is to be understood that other relays such as commonly used in railway signalling will be interspersed as required between these relays and switch machines or the like requiring relatively large operating currents. It should be further understood that the latter relays will be provided with any necessary holding circuits to sustain them, when operated, till the movement of the controlled unit is completed. The circuits shown in Fig. 13 as described are adapted to hold closed until completion of the control code and for several time channels thereafter, or for a period sufficient to operate any required secondary relay or contactor; but not necessarily sufficient to complete the movement of the controlled unit.

Fig. 14 shows the means provided for driving sub-station dials 205, 207, 209, 210, and 218 of Fig. 13 in synchronism with the central station dials. 221 is a commutator at the central station completing one revolution during each two time channels of dial switches 21 and 22. It may, for example, be mounted upon the shaft of a motor by which the dial switches are driven. When switch 224 is closed the commutator connects a separate synchronizing line 225 during the time channels to the positive and negative poles of battery 223 which is grounded at its center. The synchronizing line extends through all connected sub-stations to ground at the end of the line, and is traversed by alternate positive and negative current impulses, each alternately coinciding with one time channel of the signalling currents in line 9 of Fig. 13. At sub-station 3 the line current traverses the coils of a polarized magnet 226 to the armature 55 of which are attached a pallet 227 engaging a single tooth ratchet 228 and a pallet 229 engaging a 24 tooth ratchet 238. Both ratchets are attached to the shaft of dial switch 205. Dial switches 205 and 216 as shown in Fig. 13, are also mounted on the same shaft, but are not shown in Fig. 14. The same shaft is frictionally driven by a gear 231 meshing with a pinion on the shaft of a direct current motor 232 taking current from the sub-station battery 19.

The motor 232 drives the gear 231 (and thereby urges the shaft) at a speed slightly in excess of the synchronous speed, but the shaft is subject to stoppage by the pallets 227 and 229. As current in the synchronizing line alternates in step with alternate time channels of the signaling dials the pallets swing alternately to the left, as shown, or to the right. Thus, pallet 229 is released during every other time channel and returns during each intermediate time channel. Since there are 48 time channels in the full program and 24 teeth in ratchet 230 there is also one tooth for every other time channel. And since the speed of gear 231 slightly exceeds the synchronous speed, each tooth of the ratchet will reach pallet 229 a fraction of a time channel in advance of the synchronous instant, and will be released in exact synchronism by the pallet 229.

Commutator 221 and ratchet 226 should preferably be so adjusted with respect to the associated dial switch segments and with respect to electric and mechanical lag of the system that the points of momentary stoppage of the ratchet will coincide with the center of the contact periods at the segments.

The elements described insure that some initial relation of central station dials 21 and 22 and sub-station dial 205 will be maintained since the sub-station dial advances by two segments for each like advance at the central station. But they do not insure that the initial relation will be the correct relation. Switch 224 and ratchet 226 with pallet 227 are provided to set the dials at all sub-stations in step with the central station dial when first started or after any general or local interruption. If switch 224 is left in its normal position the central station opens pallets 227 and 229 will swing to the right at the next negative impulse and stay there. Pallet 229 will then remain disengaged and the shaft will advance at the speed of gear 231 until pallet 227 engages ratchet 226. At that point the shaft will stop and remain until positive current is again supplied by closing switch 224. If the interruption of positive current is for the duration of one full program or more, and if positive current is restored at the right point in the program, all sub-station shafts will be stopped at the same point and will start in step with shaft 20 at the central station. In order that starting may be accurately timed in step with shaft 20 the switch 24 should be interlocked with the shaft; and if desired it may be operated by the shaft at regular intervals such as once in each fifty revolutions of shaft 20.

At sub-station 4, parts 226, 227, 228, 205, 231, 232, and 19 are as described at sub-station 3. But ratchet 230 with its pallet 229 is replaced by a synchronous motor 233 connected in series with magnetic 226. Since the speed of gear 231 slightly exceeds the synchronous speed it will tend to drive the synchronous motor above synchronism, and will cause it to function as a synchronous generator, returning energy to the line, so that the motor will be equivalent to ratchet 230 in limiting the speed of rotation to synchronous speed. No provision for starting motor 233 from rest is required because this function is performed by motor 232; but motor 233 must have enough synchronizing power to pull into step from the slight over-speed of gear 231 against the frictional driving force of gear 231. If switch 224 is open the average torque of motor 233 will be diminished. It may or may not suffice to hold the motor in step with the line impulses. In either case the shaft will advance until stopped by pallet 227, and may then be started in step with the central station dials by closure of switch 224, as described at sub-station 3.

If motor 233 is of a self-starting type, and if its torque when supplied with negative half waves only is sufficient to drive the shaft when started, gear 231 and motor 232 may be omitted. The apparatus will still function as described. If alternating current from interconnected sources is available at the central station and at all sub-stations, as will often be the case, all dial 75
switches at the central station and sub-stations may be driven in synchronism by self-starting synchronous motors as at 233. In this case commutator 224 may be omitted. Magnets 226, 227, and ratchet 228 will still be required to set the various dials in step initially and after interruptions. Magnets 226 may be controlled over a separate synchronizing wire 225, as shown, or an equivalent channel may be provided on control wire 8 (Fig. 1 to 13) by well known expedients such as super-position of alternating current on the direct current circuit, or the various duplex arrangements of the telegraph art.

In many aspects the various features of the present invention are applicable to all types of train dispatching systems, and particularly to those in which devices at the control station and sub-stations are operated in synchronism. As generally used, the word “synchronism” is applicable both to independently and dependently timed devices; in other words, two devices may be said to operate in synchronism where they are driven by two independent but identical clockworks, and they may be said to operate in synchronism also where one device is operated by a clock and causes the operation of the second device in step-by-step or in connection with each other, purely in accordance with the use of our invention, devices such as distributors at the control station and at the substations, are independently timed and operated, the only timing connection between the two being a single impulse by means of which the two devices are started off together or stopped together. To distinguish from those systems often called synchronous, in which a one-to-one correspondence of events (such as local line wire connection changes) is produced at distant points by means of which we have frequently used hereinbefore, and particularly in the claims, the term “time channel” on a certain conductor. Often we have used “time channel” without specifying the conductor on which the time channel is conveyed, and the latter is not readily understood. “Time channel on a conductor” is a term used for many years in those synchronous telegraph systems largely dependent on independent time measuring means for keeping in step and one never quite as well by means of which are used for keeping in step. The essence of the term is the sole reliance, during some interval, on pure time measurement for keeping in step. Whenever we have used it we have done so in the exact meaning of the following definition:

A time channel on a conductor is one of a definite number of periods of availability for different uses of that conductor that are repeatedly measured off in the cycles of two or more independent cyclic timers synchronously changing the local relations of that conductor at two or more different places, which timers are put in step once per cycle.

A time channel is not a mere instant of time, else there would be an infinite number, but is a specific conductor made available for a specific part of a recurring time cycle.

What is claimed is:

1. In a train dispatching system, a control circuit associated with a control station and a plurality of substations, means at said control station for establishing time channels on the control circuit and transmitting certain codes of impulses during the time channels, a code receiver at a station including independently means for establishing the time channels in cooperation with said first mentioned means, a source of coded impulses, and a signal transmitter at the substation operatively dependent upon coincidence of one of the codes of current impulses and the code independently established by said code receiver.

2. In a train dispatching system, a control station, a plurality of substations, operating units at said substations, a circuit interconnecting said main station with said substations, means for establishing cycles of time channels on said circuit, an impulse transmitter at the main station for sending to said substations unit operating signals during said time channels, means for establishing a calling code during each cycle consisting in current flow during three among seven channels, an impulse receiver at each substation, and means responsive to the completion of the calling code to start the receiver in step with said transmitter at the substation represented by the calling code.

3. In a train dispatching system, a control station, a plurality of substations, operating units at said substations, a connecting conductor between said control station and said substations, means for establishing time channels in synchronism with said conductor means including a sender and a source of current at the control station for selectively controlling said units by applying currents of varying polarity on different ones of said time channels, an indicator at the control station responsive to said units, a receiving circuit at a substation cooperating with said sender for controlling the operating units thereat and responsive only to an impulse on a certain time channel when said impulse bears a predetermined relationship to impulses on other time channels and an indicator at another substation made responsive to an impulse on said certain time channel for controlling said indicator when the last mentioned impulse bears a different relationship to impulses on other time channels.

4. In a train dispatching system, a control circuit and a source of current associated with three stations, means including a distributor at one station establishing alternately a group of message time channels and a group of call time channels, means for establishing three conditions with respect to current on said time channels, one of which conditions is reserved exclusively for and distinguishes one of said groups of time channels, a call receiver and a message receiver at another station respectively responsive to current conditions on said call and message time channels, and a stopping means for each receiver actuated only at the start of the corresponding group of time channels.

5. In a train dispatching system, a master distributor, several secondary distributors, a line interconnecting said distributors, separate and regulated motor means associated with each distributor, means for transmitting periodically over said line a start pulse to start all said secondary distributors in unison with said master distributor whereby time channels are established on said line, means for transmitting a symbol of pulses on time channels intermediate successive start pulses to maintain one of said secondary distributors in unison with said master distributor, and means for transmitting train dispatching control symbols on other time channels.

6. In a train dispatching system, a control station, a plurality of substations, operating units at each substation, a connecting circuit between said 25 17 2,111,852
control station and said substations, a receiver including an electronic relay at each substation for controlling said units, anode, cathode and grid electrodes for said relays, a connection between the grid and said circuit, a bias battery in said connection, means at the control station for establishing time channels over said circuit, means at the substations for applying alternating current potential to the plate at a greater frequency than the establishment of said time channels, and means at the control station for varying the potential of said circuit during time channels.

7. In a train dispatching system, a control station, a plurality of substations, operating units at said substations, a connecting circuit between said control station and said substations, means including two three-electrode valves at the substations for controlling said units, means at the control station for selectively controlling said valves over said circuit, a connection between one electrode of one valve and one side of said circuit, and a connection between another electrode of the other valve and the same side of said circuit.

8. In a train dispatching system, a control station, a plurality of substations, operating units at each substation, a connecting circuit between the control station and the substations, means including two valves at each station for controlling said units, means at the control station for selectively actuating said valves, anode, cathode and grid electrodes for said valves, a connection between the grid of one valve and one side of the circuit, and a connection between the cathode and the other valve and the same side of the circuit.

9. In a train dispatching system, a control station, a plurality of substations, operating units at said substations, an indicator and a source of direct and two sources of alternating currents of different frequencies at the control station, a polarized and a neutral magnet at each substation for controlling the operating units, a condenser at each substation, a network tuned to prevent passage of alternating currents of the frequencies generated by said sources, a circuit extending from said networks with said circuit, means for establishing time channels on said circuit, and means for rendering effective said network operable switch, said network and said switching means during predetermined channels.

10. In a train dispatching system, a control station, a plurality of substations, operating units at said substations, an indicator and a source of direct and two sources of alternating currents of different frequencies at the control station, a polarized and a neutral magnet at each substation for controlling the operating units, a condenser at each substation, a network tuned to prevent passage of alternating currents of the frequencies generated by said sources, a circuit extending from said networks with said circuit, means for controlling said units including said polarized and neutral magnets, a variable network switch in said circuit at said control station, a branch to said circuit at each substation; a switch at each branch, means controlled by the associated operating units for controlling said switch, two paths at each substation each tuned to a different current frequency, and means for associating any one of said last mentioned networks with said circuit.

11. In a train dispatching system, a control station and a plurality of separated substations, a line wire through which the central and said substations may be interconnected, a speed-regulated transmitting distributor at central station initially making connections to said wire, receiving distributors at said substations, speed regulated independently, cyclically making connections to said wire in phase with said transmitting distributor for completing between central station and said substations on said wire several distinct operative connections in succession, called time channels, means at the central to transmit on these time channels codes of impulses distinguished by their time channel use and selectively receivable by individual substations, said speed-regulated distributor being provided with a plurality of wipers, means for revolving said wipers together, a set of contacts cooperating with each wiper, a wiper distributor related to said speed-regulated transmitting distributor, and means for operating said wiper distributor to make one revolution for several revolutions of the transmitting distributor wiper, thus connecting said line wire to a different wiper of the transmitting distributor during different revolutions of the latter.

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