Remote Supervisory Control.

G.E.C. Tandem System Installed on Winchester Corporation Electricity Supply Network.

OF the various kinds of apparatus employed in automatic telephony none is more simple in conception than the relay and the uniselector, but the demand made upon these elements by a modern telephone system has made necessary careful design and manufacture to ensure unfailing accuracy and continuity of operation. Although developed for telephone purposes their characteristic features make each capable of application outside the sphere of telephony and a more general appreciation of their merits is leading to an increasing use in other fields.

An application which shows how the world of heavy engineering may benefit by co-operation with the communication engineer is found in the control of variable apparatus from a remote point. On water supplies, sewage works and electric power distribution systems, to quote typical instances, the operation of plant at outlying points is becoming increasingly subject to centralised control since concentration of control and supervision is not only essential in maintaining a continuous service but also results in valuable economy in operating costs.

In administering from a central control point such systems as those instanced it is necessary not only to provide for the remote control of the plant but also for the conditions obtaining at various points on the system to be indicated at the control station either automatically or on demand. If these requirements are met supervision and control of the entire system may be effected from one point. To this end The General Electric Company developed a remote supervisory control equipment depending for its operation on the action of relays and uniselectors. It is the present purpose to describe the most recent application of this equipment, namely, for control and indication on the A.C. distribution system of the Winchester Corporation Electricity Department.

Fig. 1 shows the layout of the area served and it will be seen that a ring main encircles the city. National Grid feeders from the Central Electricity Board substation at Nursling feed power at 33 kV to St. Cross Substation, where two 2000 kVA transformers supply the ring main at 11 kV. At the substations the ring main voltage is transformed to 400 and 230 volts for the local supply. Particulars of the types of substations and their present capacities are also given in Fig. 1.

The ring main is divided into two parts, termed Ring Main East and Ring Main West, and the switching arrangements enable the two halves to be fed individually or as one complete ring as conditions demand. A substation may be disconnected without breaking the continuity of the main.

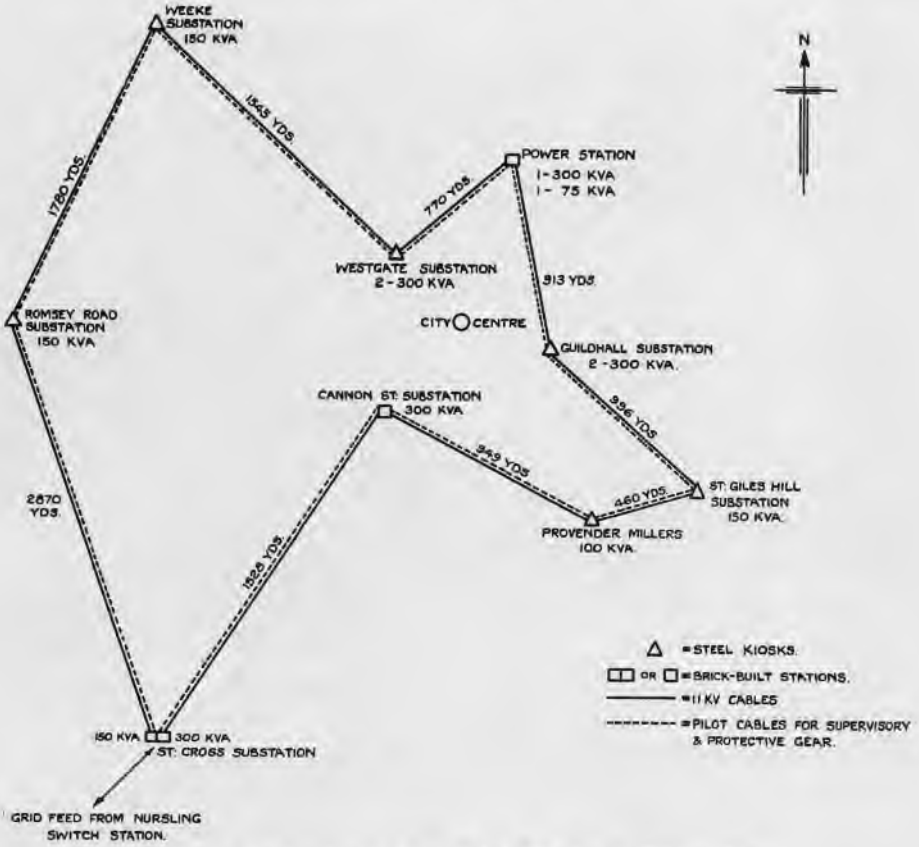

Fig. 1.—A.C. Distribution System of the Winchester Corporation.

Protective gear is interconnected between the substations by a pilot cable which also carries the four pilot wires necessary for the operation of the supervisory control apparatus.

Control is centralised at the power station and the supervisory equipment performs the following functions :—

(*a*) Indicates oil circuit-breaker positions.

(*b*) Operates transformer tap changing equipment, showing at the same time a reading of the L.T. bus bar volts, and indicates in each case the transformer tapping.

(*c*) Indicates, on demand, the L.T. bus-bar voltage.

(*d*) Indicates, on demand, transformer load.

(*e*) Gives telephone facilities between all stations on the ring main.

These indications are given at the control point in respect of each substation and tap changing of any transformer may be effected by the control officer.

The supervisory control equipment at each substation consists of a uniselector and associated relays fitted in a wood cabinet, a hinged lid providing easy access for inspection of the apparatus. A similar cabinet accommodates metering transformers and relays, whilst a telephone is mounted in a convenient position. Current for both the supervisory equipment and the circuit breaker

tripping mechanism is supplied by a common 30 volt storage battery of 20 ampere-hours capacity, trickle charged from the A.C. supply. The two apparatus cabinets as equipped at each of the substations are shown in Fig. 2.

All the apparatus at the control station, with the exception of the telephone, is fitted inside the control cubicle shown in Fig. 3. On the front of the cubicle are mounted a number of panels, shown separately in Fig. 4. Each is associated with a substation and carries rotary keys representing the oil circuit breakers at the particular substation and lever type keys designated respectively, "Station Select", "Voltmeter", "Ammeter", "Tap Raise" and "Tap Lower". Adjacent to each key is an associated lamp, whilst a large red station lamp is mounted at the top of each panel. The knobs of the rotary keys are designed to form part of a diagram painted on the panels to represent in mimic form the H.T. ring main, L.T. bus bars and the switching arrangements. This diagram is seen in Fig. 4, the positioning of the panels being in accordance with the geographical layout given in Fig. 1.

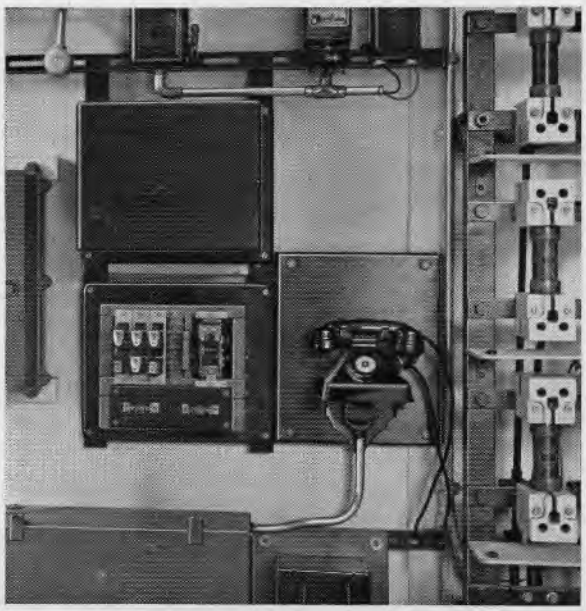

Fig. 2.—Substation Supervisory Control Cabinets.

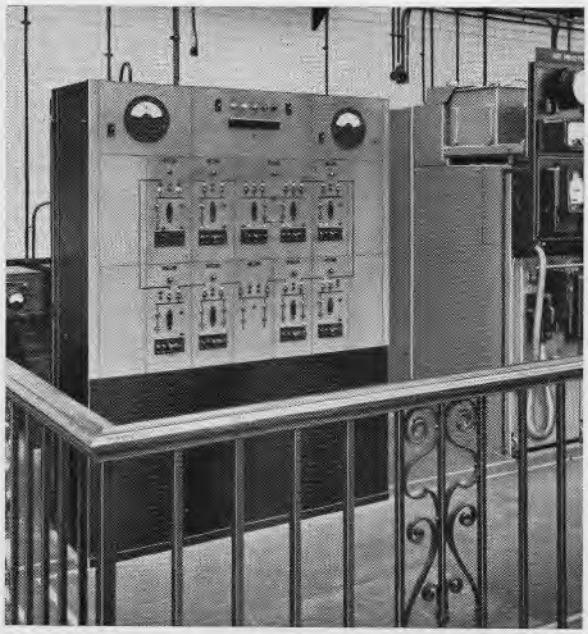

Fig. 3.—Supervisory Control Cubicle at Power Station.

An accurate forecast of the probable developments of a distribution system must always present a little difficulty and this system is no exception in that respect. However, a notable feature of the G.E.C. supervisory control equipment is its flexibility, enabling future developments to be readily catered for. Each substation panel on the control cubicle is complete in itself and is jacked in on the panel mounting, being secured by four fixing screws. Four spare panel positions are provided and thus, if a substation is added to the network, the necessary apparatus at the control point is very simply added by jacking in a further panel suitably equipped with keys and lamps. The additional substation is linked up for supervisory control merely by extending the pilot wires.

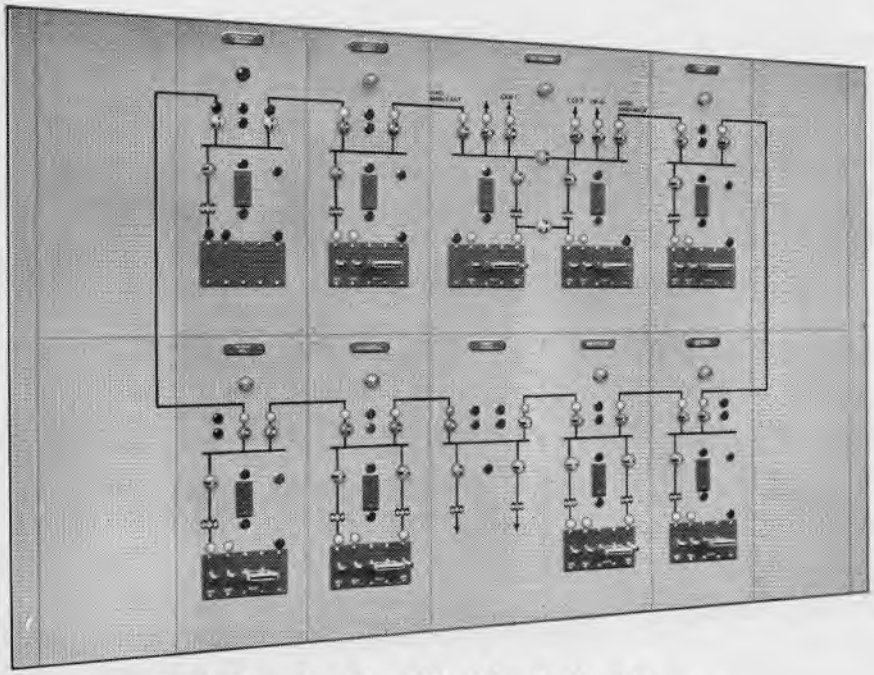

Fig. 4.—Supervisory Control Panel showing Mimic Diagram.

Above the substation panels on the control cubicle is mounted a panel which carries an ammeter and a voltmeter together with the transformer tap indicator and various keys referred to later.

The control station telephone set is fitted inside a special silence cabinet, the calling signal being provided by a klaxon horn.

A 50 volt battery of 25 ampere-hours capacity is trickle charged from the mains and supplies current for the operation of the supervisory control apparatus at the control point.

From the description of the operation which follows it will be seen that lamps do not glow continuously; a lamp lights only when an indication is to be given. This ensures that the maximum service life is obtained from the various lamps and that current consumption is reduced to a minimum.

Operation.

The substations are normally unstaffed and it is important that an automatic change in a breaker condition be at once made known to the control engineer. Further, manual operation of the circuit breakers is effected by a visiting attendant acting upon instructions and it is necessary to provide assurance to the control engineer that the instructions have been correctly carried out.

In consequence, any change of state of the substation switchgear is immediately signalled automatically to the control point.

When a breaker has been operated, either automatically or manually, the control engineer's attention is drawn to the control cubicle by a loud-ringing bell and then the glowing of the red lamp on the particular substation panel on the cubicle indicates that a change is to be signalled from this substation. The engineer operates the "station select" key on this panel, which extinguishes the lamp and causes the calling substation to be connected to the control point in readiness for the indication. This connection is effected on a system of selection carried out automatically by the control apparatus and a check on the correctness of the selection is given, since, when this operation is complete, the station lamp again glows. The apparatus then automatically compares the position of each circuit breaker at the selected station

with the position of the corresponding rotary key on the control panel and on encountering the discrepancy due to the operation of the breaker the lamp adjacent to the appropriate rotary key lights, continuing to glow until the key is changed. The comparison is then automatically continued until all the breakers at the station have been checked. By responding to the lamp indications the control officer brings the mimic diagram in complete agreement with the conditions on the distribution system and may then restore the "station select" key.

The tap changing of transformers is under the control of the engineer and is effected by operating the appropriate keys on the control panel. To change the tapping, the substation is selected by operating the "station select" key, the station lamp glowing to indicate correct selection, and then the "tap raise" or "tap lower" key is operated as desired to cause an appropriate contactor at the substation to be selected in readiness for operation. The lamp adjacent to the key operated glows, indicating that conditions at the substation are correct. On the top panel of the control cubicle is provided a key designated "operate" and this is now depressed to operate the contactor at the substation, causing the tap changing switch to take one step. Since the purpose of tap changing is to regulate the voltage it is important that a reading of the bus bar volts be readily obtainable. After a tap change has been made it is not necessary to perform any further operation to read voltage since the voltmeter on the cubicle panel is automatically associated with the bus bars on which the voltage is being varied and thus the effect of changing the tapping is at once visible. On restoring the "operate" key the voltmeter is disconnected and a numeral on a glass screen is illuminated from behind to indicate the position of the tap switch. If the voltage is not of the desired value the "operate" key is again depressed causing the tap switch to take a second step and the voltage to be indicated. Adjustment of the bus bar voltage is thus effected merely by depressing the "operate" key, restoration each time resulting in an indication of the tapping being given.

At any time the bus bar volts or the load on a transformer may be read on the appropriate meter. Selection of the particular substation is made by means of the "station select" key and then a "voltmeter" or "ammeter" key is depressed as required. The station lamp glows and the lamp adjacent to the key operated lights to indicate correct selection. When this condition obtains, a key adjacent to the meter is operated to connect the meter in circuit and the required reading may then be taken.

Full co-ordination of the stations is completed by providing telephone communication over the pilot wires. The telephone at the control point is fitted with an automatic dial enabling any substation to be called by dialling an allotted number after a key on the instrument has been operated. Any substation may call the control point by throwing a key on the telephone set. After a reply is received the key at the calling station is restored and releases the supervisory control apparatus, which is then free to indicate any change which may occur on the system. Thus telephone conversation over the pilots in no way affects indications of changes on the distribution system.

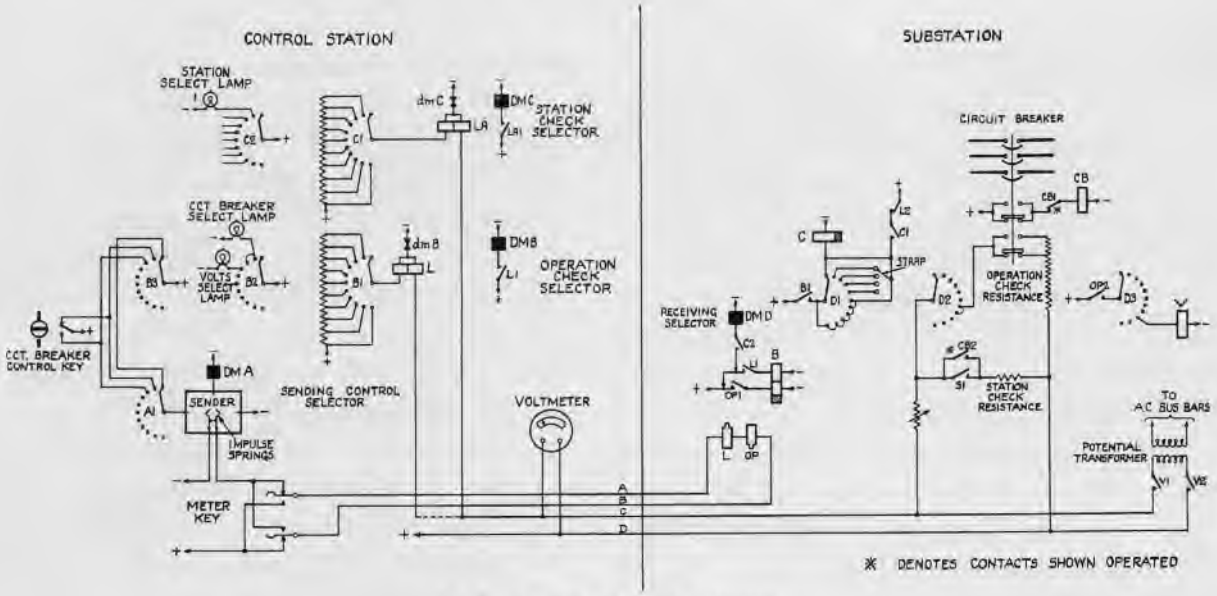

Fig. 5.—Simplified Circuit Diagram.

Circuit Operation.

Fig. 1 shows that the substations are linked in tandem by the pilot wires and thus the first action of the apparatus when an operation is to be performed is to select the required substation. As has been stated, the substations are divided into two groups forming ring main East and ring main West respectively. The first step in the selection is to select the group and this follows upon the operation of the "station select" key on the appropriate panel on the control cubicle, the operation of this key causing a relay to operate to disconnect the pilot wires to the other group of substations.

Each substation is given a distinguishing number and selection of the required station in the particular group is effected by a series of impulses. The operation of the "station select" key causes a sender at the control station, consisting of a relay chain, to establish a loop on pilot wires A and B seen in Fig. 5. The L relays at all substations in the group operate over this loop and in each case contacts L1 operate relay B. Contacts B1 operate relay C, which at C2 energises the driving magnet (DMD) of the receiving selector. The substation circuit shown is for a station the number of which is 14 and since this particular "station select" key is depressed the sender will first send one impulse. The L relays at each station respond and at L1 cause the respective receiving selectors to take one step. The wipers of this switch at each station are now resting on the second bank contacts and at the station required wiper D1 maintains a circuit for relay C since this second contact is wired to a terminal strapped as shown. Only at this particular substation is the strap wired and thus all other C relays release. Relay S operates when the receiving selector stops on the selected station contact and at S1 connects a resistance across the pilots C and D. The value of this resistance is characteristic of the substation and permits a predetermined

current to flow in one winding of relay LA at the control station. LA operates and at LA1 energises the driving magnet (DMC) of the station check selector, causing the contacts dmC to open. This releases LA and causes the selector to take one step. At the completion of the step contacts dmC are closed and current again flows through the first winding of relay LA. In addition, since the station check selector has taken one step, current flows through the second winding of relay LA. This relay is differentially wound and if the currents in the two windings are not of equal value the relay will again operate, causing the selector to take a second step. This cycle continues until a balance is found, which will denote that a resistance has been selected corresponding to the resistance at the substation. Obviously this is a check on the correctness of selection of the substation and when this condition exists circuit arrangements provide for the glowing of the appropriate substation lamp connected to the bank C2. The second digit of the station code number (in this case 4) is now sent and in effect serves to check that the supervisory control apparatus is ready to receive further impulses for selection of the substation equipment.

The circuit diagram (Fig. 5) is given in a simplified form and shows only one circuit breaker and the associated key together with a potential transformer and the control panel voltmeter. This simple representation is, however, sufficient to convey an understanding of the operation. After the substation has been selected in the manner described the positions of the circuit breakers are automatically checked in comparison with their respective keys on the control panel. Circuit arrangements cause the control of the sender to pass to wipers A1 and B3. Positive battery from wiper B3 causes the sender to operate and send an impulse over the pilots and also to the driving magnet (DMA) of the sending control selector. This switch takes one step and positive battery from the circuit breaker key causes a second impulse to be sent and the switch to take a second step, becoming stationary on the third contact. It should be noted that this step to the third contact is due to the fact that the key is in the open position. The impulses are received at the selected substation and relay L responds, stepping the receiving selector to the bank contact connected to auxiliary contacts in the circuit breaker. These contacts place a resistance across the pilots C and D, the value of the resistance depending, as will be seen from Fig. 5, upon the position of the circuit breaker. Exactly as switch C at the control station responded to the loop caused by the station check resistance, so switch B now responds to the loop caused by the operation check resistance. If the circuit breaker is open this operation check resistance will be balanced by the value of the resistance found by wiper B1 when the switch has stepped to the third contact. Wiper B3 thus rests on its third contact as a result of the selected breaker having been found "open". It has been emphasised that wiper A1 rests on its third contact as a result of the associated key being "open" and the agreement thus found between the key and the breaker permits the supervisory control apparatus to pass on to the next breaker since positive battery from wiper B3 via wiper A1 serves to initiate further impulsing. A lamp connected to the third contact of bank B2 lights to indicate the breaker which has been checked.

To obtain voltage readings from any selected substation the appropriate voltmeter key on the control cubicle is depressed. Automatically a number of impulses is sent out to step switch D at the selected station to a bank contact on which wiper D3 prepares a circuit for relay V. Wiper D2 causes the appropriate check resistance to be placed across the pilots C and D resulting in a check on the selection being given at the control point. On receipt of the lamp indication that the receiving selector is standing on the "voltage" position the control engineer depresses the "meter" key. Depression of this key reverses the polarity of the pilots A and B and relay OP operates. Contacts OP2 operate relay V. Contacts V1 and V2 connect the potential transformer to the pilots C and D causing the voltmeter to give an indication of the bus bar voltage.

Should a circuit breaker position be changed either due to an automatic trip or to manual operation the fact is at once signalled to the control point. Relay CB is normally held operated via its own contact CB1 and auxiliary contacts on its associated circuit breaker. If the breaker changes its position the transition period of the auxiliary switch is sufficient to enable relay CB to release. Contacts CB2 cause the station check resistance to be placed across the pilot wires C and D. The control station apparatus responds, in the manner already described, finding the substation. The substation lamp lights and the loud-ringing bell operates. In response the control engineer operates the appropriate "station select" key causing the control apparatus to check the breakers. The associated rotary key is not in agreement with the affected breaker and in consequence the selection process is halted when this breaker is found. The associated lamp on the control panel then glows.

Although the circuit details are not shown it will be understood that the same process of selection and checking of both the substation and the equipment is applied to tap-changing and also to telephone communication.