Power Plants for Telephone Offices

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SYNOPSIS: The present paper gives a brief discussion of some of the more important problems connected with the supplying of power to telephone offices, and developments which are being perfected to bring about economies. Among the subjects discussed are the use of commercial types of charging generators together with appropriate filters, power factor correction, complete power unit assemblies for small installations, and the development of more nearly automatically controlled power installations with the object of reducing supervision.

I. THE POWER PROBLEMS

The purpose of the telephone power plant is to furnish energy of the required character in proper amount and available 100 per cent of the time. An elaborate telephone system, comprising buildings, central office equipment, outside plant lines and substation apparatus, together with a staff of operators, is rendered useless if the supply of power fails. No conversations can be held. No calls can be made and none received. In a way, the power plant might be termed the "heart" of the system, since every line and connection will be "dead" the moment the supply of power is interrupted.

Continuity

In order to meet the vital need of ever-ready power it is necessary in telephone power plants to arrange for some primary power source which is usually a commercial electric service from outside. The services are investigated with care to determine their reliability and, wherever possible, two services connected to different generating stations or systems are brought into the telephone building. In those cases where a single service only can be secured, a local means of charging such as an engine-generator set may be provided as a reserve on this service.

Even with the best commercial power services short interruptions are experienced, so that it is necessary to provide another source which shall be available at all times to operate the central office during temporary failures of the outside service. This is accomplished by the use of a storage battery of sufficient capacity to carry the load of the office during failure of the sources of power supply, the battery being continuously connected to the circuits so no interruption occurs. Common practice and experience have resulted in batteries of certain sizes being provided, these sizes being sufficient to carry the exchange

load for intervals ranging from a few hours to several days, depending upon conditions. The present practices have been successful in maintaining continuous power supply, and central offices generally throughout the country have been ready to serve, even during periods of storm, fire or other calamities.

Type of Power Needed

Power as furnished by the public service companies is not of the sort suitable for operating telephone power plants, but must be converted from a relatively high voltage alternating or direct current to a lower

Fig. 1—Incoming direct-current power for large telephone building. About 1,000 h.p. of this is provided to drive motor-generators for reserve central office use, the regular power being alternating current. Both direct- and alternating-current services are duplicated. This panel provides four feeders direct to substation and four to network, capacity 3,480 kw.

voltage direct current for talking, supervisory and signaling purposes and to alternating current of various voltages for signaling. This conversion is commonly made by means of motor-generator sets or some type of rectifier, of either the mercury arc, hot cathode or other types. Since it is impossible to use outside power as furnished, suitable reserve machine equipment must be provided capable of replacing the regular machines before the reserve energy in the central office battery is exhausted.

The low voltage charging generators furnishing the bulk of the power must be electrically quiet so that they will not cause disturbing noises in the telephone circuits. It is, of course, economical to furnish most of the energy required by the telephone equipment directly from the motor-generator sets rather than from the reserve battery, since the conversion efficiency is substantially greater and the battery investment is much less. While various direct-current voltages are required, 24 volts and 48 volts predominate.

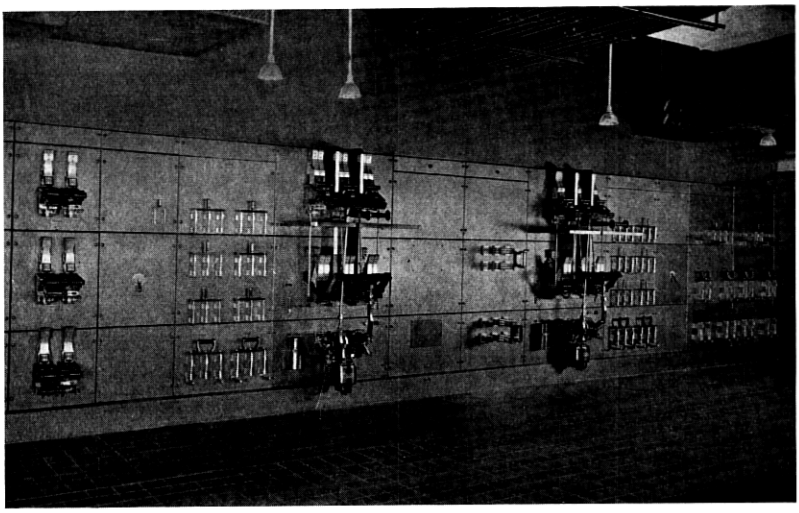

Fig. 2—Building switchboard to distribute incoming power shown in Fig. 1. The 5,000-ampere circuit breakers switch the important load circuits from this panel to a similar reserve panel fronting on a different street.

The signaling machines and batteries, while of relatively small output, are subject to rather exacting performance limitations. Twenty-cycle alternating current of approximately sine-wave form, at nominal voltages of 105, 100, 85, 77, etc., is needed for ringing on different types of circuits. For four-party selective ringing, positive and negative direct currents are superimposed upon the alternating current to secure wave shapes especially suited to the operation of biased ringers. For machine ringing, the 20-cycle current is divided into one or two second ringing periods separated by silent intervals during which direct current is provided for operating the tripping relay and stopping the ringing when the called subscriber answers.

For ringing over composited toll lines a higher frequency, which will not interfere with telegraph operation, is required and 135 cycles is

provided. For other types of toll circuits "voice-frequency" ringing at 1000 cycles must be furnished.

Message registers in manual offices use direct current at 39 volts, coin collect and refunding operations require positive 110-volt and negative 110-volt direct current, while "tones" of approximately 160 and 480 pulsations per second are needed for giving various signals to the operators and the subscribers. A graduated tone, like a siren, is required for the "howler" used to call the attention of a subscriber to a telephone receiver left off the hook. Various flashing signals and combined tones and flashes are also used, such for example as the "busy" signal.

Operation and Maintenance

In addition to being designed for furnishing power of the required characteristics, the machines and apparatus must operate for long periods with a reasonably small amount of operating attention and maintenance. Due to the narrow requirements being placed by the circuits upon the power equipment and the more frequent readjustments required, it is becoming necessary in many cases to furnish automatic voltage regulation. As the cost of labor increases, it will become still more desirable to provide equipment which will largely run and regulate itself.

Sizes of Power Equipment

It has been stated at different times by people connected with the telephone companies and also by outsiders that the amount of power required to carry on telephone conversation is microscopically small, if not negligible. This perhaps is true when considering merely the small amount of alternating current which travels over the line and operates the diaphragms of the receivers. The great sensitivity of this instrument permits operation on very small energy.

There is, however, a large amount of equipment in the central office, including relays, lamps, and other apparatus, which must function in order that this small talking current may be provided and may go from the subscriber who wishes to talk to the subscriber he desires to reach. When this apparatus is multiplied for the thousands or even hundreds of thousands of conversations per day which may be supplied from a power plant serving two, three or perhaps more central offices, the size of equipment needed becomes quite substantial. In these multi-office power plants several of the largest charging generators each driven by an 80 h.p. motor, as well as a number of smaller charging sets may be required, while two batteries of the largest storage battery cells manufactured may be used in parallel to give the necessary battery reserve.

Some of the large telephone buildings house several central offices and, in addition, administrative, engineering, commercial and other departments. A joint incoming power service is often provided for such a building, of which the initial telephone power plant requirements may approximate 500 h.p. with an estimated energy consumption approximating 1,000,000 kw.-hrs. per year. Provision for double this demand in the ultimate may be made.

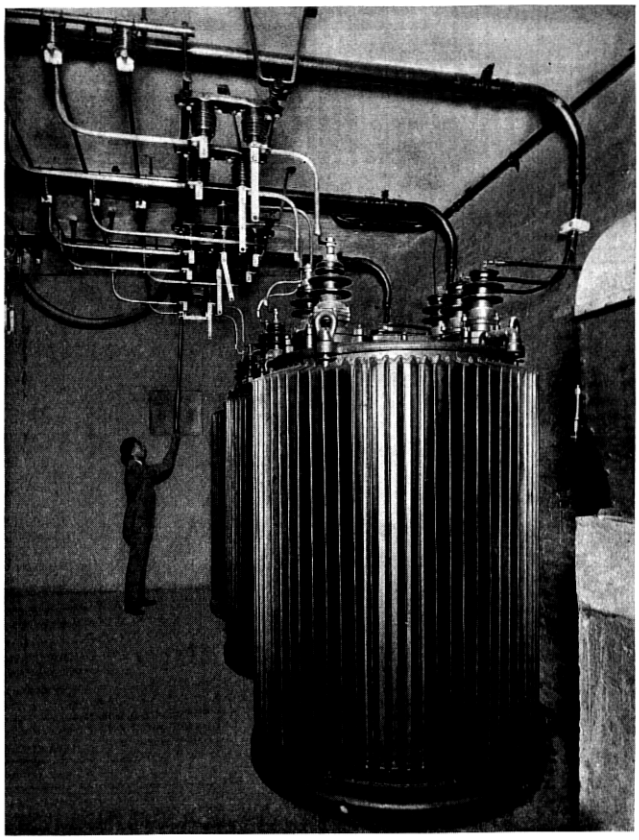

Fig. 3—Typical large transformer installation for breakdown service when two types of alternating current are furnished. Three 333-kv.-a., 11,000/2,200-volt transformers supply frequency changer, these being in addition to the 60-cycle transformers for regular service.

The range of sizes is very great, varying from the above down to the small "magneto" office which operates largely on dry cells and other primary batteries, and may also take 1/8 h.p. to run a magneto ringing machine from the power service. In such offices without

electric power supply, all the equipment must be operated from primary batteries. The "magneto" office, so-called, is one which serves "local-battery" subscribers each of whom has dry cells and a hand ringing generator or magneto. In the larger "common-battery" systems all the power for both talking and signaling is provided from sources at the central office common to all subscribers.

In dial offices it is evident that more power equipment is required, since the processes of connecting through the circuits are performed by machine instead of by operators.

Cost of Power

The cost of power as purchased from the public service companies varies largely, depending upon the location, the amount purchased and to some extent upon the characteristics of the load. In large cities, power is billed at from 2 to 5 cents per kw.-hr. Usually a sliding

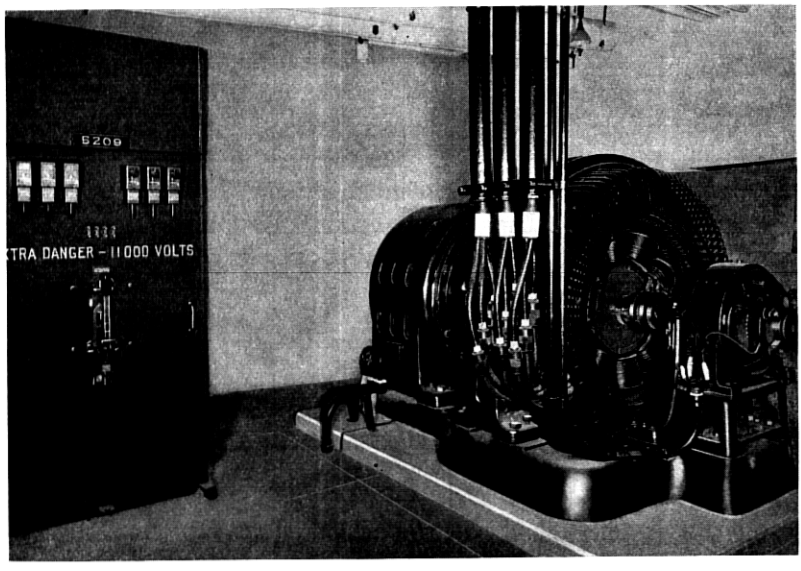

Fig. 4—Frequency changer set for breakdown service, 650-h.p., 25-cycle, 2,200-volt to 600-kv.-a., 60-cycle, 220-volt. Emergency power controlled by 11,000-volt truck switch.

scale is offered and the lower figures apply to purchases of alternating current in large quantities. Cities near sources of soft coal supply or near large water power developments get cheaper rates, in some cases being nearer 1 cent than 2. In small offices, power usually costs between 5 and 10 cents per kw.-hr., running as high as 15 cents in a

small percentage of outlying rural offices. For studies involving the use of power furnished from a telephone power plant, it will, of course, be necessary to consider the cost of the machine and battery equipment, of the floor space and of the operating attendance in addition to the cost of the "raw material" power as purchased. A fair overall figure, including these charges, might approximate 30 cents per kw.-hr. for a typical dial office, or 40 cents for a typical manual office, the higher charge for manual offices, in general, being accounted for by the fact that the quantities purchased and used are less, involving somewhat higher purchase price and overhead. It should, of course, be appreciated that the amounts will vary considerably with local conditions including the type of equipment used and the "load factor," or the distribution of load throughout the day and night. In most telephone power plants this factor is unfavorable for low cost power since most of the traffic is concentrated within a few hours of the twenty-four. The cost of energy varies also during the life of the same office, being higher during the early years and lower when load on the power equipment more nearly approaches capacity.

II. Some Developments to Meet the Power Plant Problems

The objectives toward which development work is directed are improved service, reduced cost, simplification of installation and decreased maintenance. Under these headings one of the most important developments at the present time is the use of commercial type charging generators.

Commercial Type Charging Generators

Charging motor-generator sets furnish most of the energy used in telephone power plants. Up to the present time "telephone generators" have been built to give an electrically smooth direct-current output which will not cause interference with conversations when furnishing current to the telephone circuits. They have also been made mechanically quiet so as not to interfere with nearby testing. They are quite special in construction, including smooth core armature and brass gauze brushes, and are subject to certain limitations which make them larger and considerably more expensive to build than ordinary machines of the same capacity.

Filters consisting of choke coils and high capacity electrolytic condensers have been developed, and with these filters commercial type charging generators can be used to float or charge the central office battery, and this type of generator is now being made available. The purpose of the filter is to make the current from the discharge

leads of the power plant sufficiently quiet for talking battery supply. It is also possible to use a somewhat higher speed machine which is smaller than the present type. The usual slotted mica commutator construction and self-lubricating carbon brushes are employed. While the mechanical noise tends to be greater because of the higher speed and the carbon brushes, it has been found that this is not a factor of importance under present conditions where power plants can usually be located more or less by themselves and well removed from the Wire Chief's testing equipment.

Filters

A new type of choke coil has been developed for the filter used with commercial type generators. It is of the enclosed shell type design having short air gaps, using the materials more economically and having a higher inductance than the coils which have been available

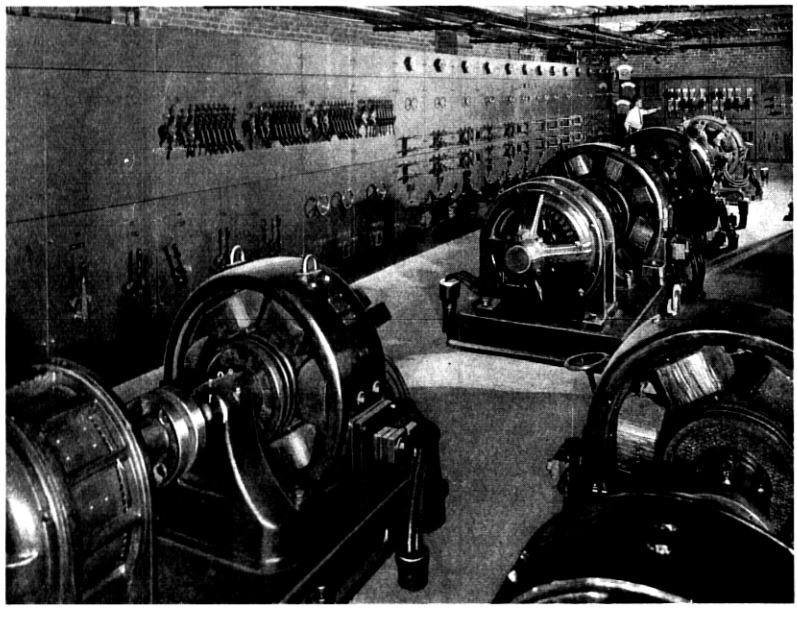

Fig. 5—Part of power room for two large panel units as provided five years ago. Twelve motor-generators for both alternating-current and direct-current service with power switchboard at left and battery control board in background. This was an alternate arrangement to use of large motor-generator to make both kinds of power available.

heretofore. Associated with this coil is a group of electrolytic condensers each of which has upwards of 1,200-mf. capacity on 24 volts, or roughly half this amount on 48 volts.

For one of the larger motor-generator sets the cost of the first set, including a filter, is about the same as that of the former "telephone generator" type outfit. The cost of the additional sets used in the power plant, which under present conditions are not provided with individual filters if a common filter is placed in the talking discharge circuit, is about half that of the present type sets.

Power Factor Correction

In connection with the new generators, synchronous motors are being made available for use where it is desired to improve the power factor of the load. The synchronous motors will be arranged to give

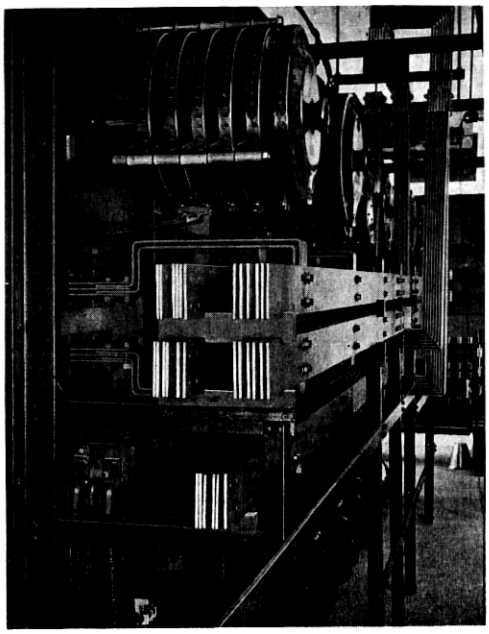

Fig. 6—Generator end of control switchboard, as provided five years ago, rear view. Six 1,000- and 1,500-ampere generators, bus bars terminated for growth when additional units required.

0.8 leading power factor, so all motors in the plant will not need to be of this type. The standard induction motors which are cheaper will be retained, both types thus being available to meet all conditions. For existing installations requiring a moderate amount of correction to avoid the imposition of penalties and where no new motor-generator sets are to be added, static condensers are available to improve the power factor and thereby reduce the excess charges on the power bill.

The addition of these is more economical than new synchronous motor-generators unless the replaced sets can be used to good advantage elsewhere.

Power Switchboards and Bus Bars

Two recent developments are now in use which will reduce the cost of control equipment and will have other advantages. Long power switchboards for large power plants had to be designed in detail and built individually. The use of unit control panels in power boards and battery fuse panels now permits layout of a simple schematic from which a power board can be assembled, using units which may be stocked as demand warrants. Considerable engineering expense is thus avoided since it will be unnecessary to work up the rather elaborate detailed drawings previously required for each major installation.

A further development of this idea is the "semi-remote control system" recently adopted. With this system most of the control equipment for each motor-generator set is located upon unit panels mounted at the set, thus reducing the main power board to small dimensions and giving increased flexibility which is particularly useful in connection with additions. Overhead bus bars and conduit are employed which are not installed till needed. The flexibility also aids in utilizing improvements and changes in the art occurring between the initial equipment installation and the additions made from time to time as the growth of the load requires.

From a production basis it is anticipated that this unit panel design will be easier to manufacture and to stock and that it will also be simpler to install than the earlier arrangements.

Complete Power Unit Assemblies for Small Applications

Where small amounts of power are required, the provision of storage batteries and associated charging equipment has been relatively high in cost of material and of installation. An appreciable cost reduction has been secured by the design of small power plant units complete with batteries mounted in cabinets and assembled with associated charging or floating equipment.

Crosstalk Reduction

In a common battery telephone office all subscribers are furnished with power from a single central office storage battery. There is a tendency toward "crosstalk," that is, mixing of conversations, so that fragments from one conversation might be overheard in another. This tendency is limited by so designing the battery and wiring common to all circuits that it will have very low impedance, particular attention

being given to arrangement of cables and use of large conductors. This imposes certain limitations upon the location of equipment and may involve considerable cost for copper in the larger power plants. However, by means of the electrolytic condensers, previously mentioned, located at battery fuse panels, crosstalk on talking feeders can be reduced to very low values, the limitations on floor plan arrangement can be largely removed and substantial savings in copper can be made.

Battery Reserve

In order to insure continuous telephone service in spite of failure of the primary sources of power, it has been customary, as already mentioned, to provide storage battery capacity sufficient in itself to operate

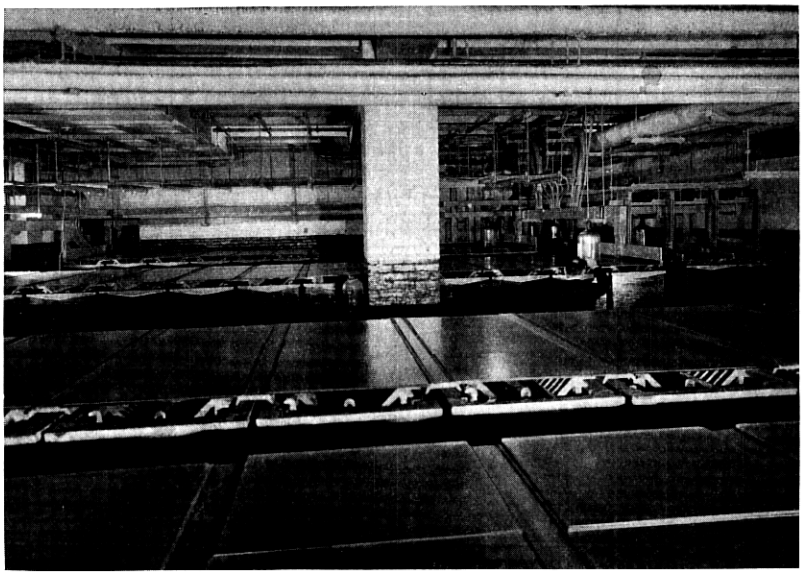

Fig. 7—Battery room for two large panel units.

the central office equipment for a considerable period. The amount of battery reserve provided depends upon the reliability of the regular outside power service and on the reserve source provided. This battery reserve may range from about three net busy hours for offices in large metropolitan districts to several days in small outlying offices. This reserve in the past has been successful in preventing suspension of telephone service due to failures of the power. With the greatly extended plant and the increasing reliability of the public service supply companies, however, the allowance of battery reserve in some cases can

be safely decreased, permitting advantage to be taken of appreciable savings in the cost of battery equipment.

Simplified Installation

The developments just discussed will, it is believed, simplify the work of installation, although certain of these developments will not necessarily decrease the amount to be done, as some of the work has

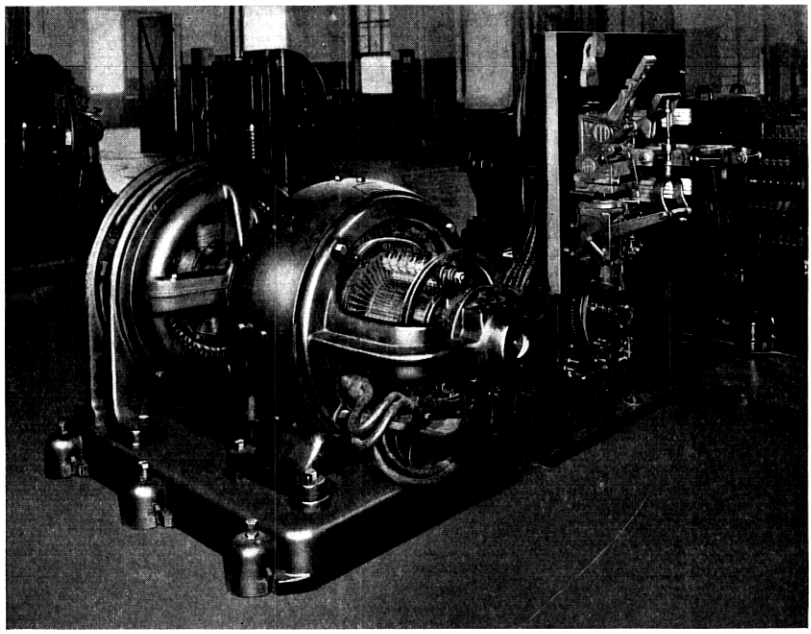

Fig. 8—Commercial type charging generator driven by synchronous motor. 52-kw. output compares with 33 kw. for the larger sized set on the right. 52-kw. "M" type generator in left background belted to gas engine.

been shifted from installer to factory and some in the reverse direction. The unit ringing control panel assemblies, for example, are being furnished wired in the shop with rows of terminal punchings to which the installer connects the wires from the generators. For charging equipment, the panels at the machines will be connected to a common overhead bus bar system, bus bars being shipped in stock lengths and cut by the installer as needed.

For small repeater and similar installations a power plant has been developed which can be placed upon shelves on a rack and connected to the power source and to the distributing bus bars. This compares with the former system of installing a number of separate units and wiring them up upon the job.

Floor plans suitable for the majority of offices are available and reasonably standardized layouts of power equipment to operate certain types of offices are found practicable.

Improved Service

Improved operation of telephone equipment is being made possible by more rigid requirements placed upon the power plant. Automatic voltage regulators for ringing generators have been in use for some time

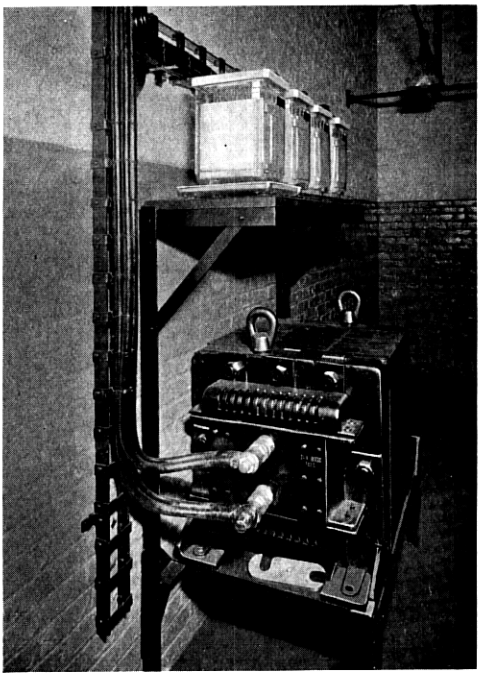

Fig. 9—24-volt discharge lead filter. 800-ampere coil, four 1,200-mf. condensers for use in suppressing generator and other equipment noises.

and the new alternating-current—direct-current system is reducing service troubles. Automatic voltage control equipment for charging generators has been developed and is being introduced. This, together with the full floating system of operating batteries, is capable of holding the main power supply for the central offices at much closer voltage limits than have been found practicable in the past, thus further stabilizing transmission and contributing to even more reliable operation of relays and supervisory equipment.

Reduction of Maintenance

It will be evident that many of the foregoing developments will reduce maintenance of power plant equipment as well as its first cost. The automatic regulating devices substantially reduce or eliminate the attention which would otherwise be required to readjust machines to compensate for load conditions. When this regulation is applied to generators which are floating batteries, it may also result in substantially increasing the life of the batteries, thus deferring replacements. The commercial generators are designed for and equipped with carbon brushes, and will require a minimum of attention.

The introduction of the enclosed type of small battery and the improvements in operating methods of large batteries are decreasing evaporation and spraying, thus reducing additions of water and the repainting of exposed equipment in battery rooms. The new methods also reduce the number of periodic overcharges or eliminate them entirely.

Combining Objectives in Signaling Machine Development

In designing new equipment it is, of course, desirable to accomplish as many objectives as possible. In this connection, mention might be made of a combination machine which may properly lay claim to attaining four important objectives, namely: improved service, reduced cost, simplified installation and reduced maintenance.

Several years ago it was the practice to secure ringing current for subscribers' bells and also for various tones and signals from a small motor-generator set, subject to generator voltage variations amounting to 35 volts as the load on the machine changed and the supply line voltage varied within stated limits. Each large central office unit required these motor-generators, one driven by a line motor and a reserve set driven by a battery motor. Direct current at + 110 and − 110 volts for controlling coin box telephones was furnished by two sets of dry cells or storage cells. In either case a third or spare battery was provided.

To replace the ringing sets and coin control batteries a combined ringing and coin-control motor-generator set has been developed and is being used except in the smallest offices, eliminating the cost and the maintenance of the separate batteries, giving closer voltage and frequency regulation for ringing, and automatically continuing service in spite of outside power failures. A description of the features of this equipment showing what it will do may be of interest as this represents a typical development.

Associated with the generator is a transformer, the primary winding

acting as a balance coil for a three-wire direct-current system and the secondary winding having taps to provide one or more of the four alternating-current voltages used with 20-cycle ringing. The generator can thus serve a toll installation at 105 volts, a dial or manual office

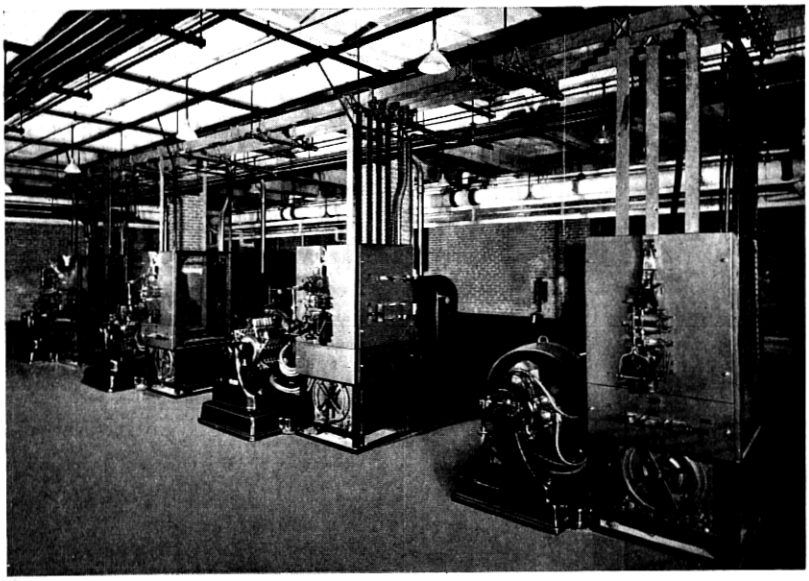

Fig. 10—Charging machines with remote controlled equipment at generator. Overhead bus bar system.

using 100 volts with the alternating-current—direct-current system and two offices, having "superimposed ringing" for party lines, one using 85 volts and the other 77 volts, the voltage used depending upon the type of subscriber sets installed in the district. Positive and negative superimposed currents are obtained by small storage batteries connected in series with the 77- or 85-volt tap of the transformer. All four types of office ringing can be secured from one machine simultaneously, though more than two is unusual. The voltage is controlled automatically within close limits, regardless of load or of normal variations in the voltage and frequency of the supply power.

In addition to ringing, the generator supplies approximately +110 volts direct-current for collecting coins and −110 volts direct-current for refunding coins, the two voltages in combination also exciting the generator field at 220 volts.

Brushes bearing on sectional and solid rings mounted on the generator shaft interrupt battery current and provide a high tone of 480

and a low tone of 160 pulsations per second which are used for various signaling purposes.

Through a 120/1 worm gear reduction an auxiliary shaft is run at 10 r.p.m. Attached to one end of this shaft is a "low-speed inter-

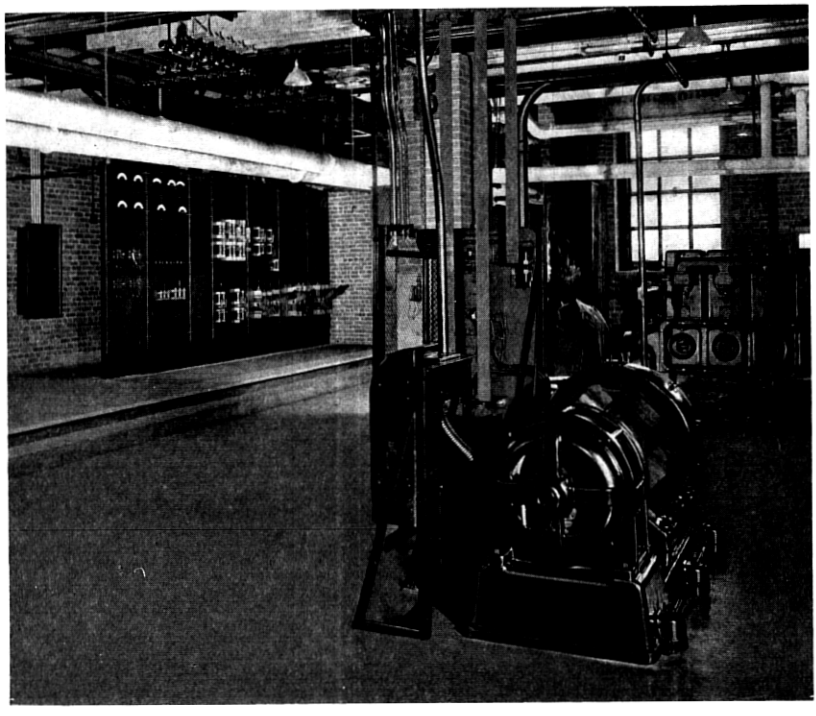

Fig. 11—Master control board for all charging sets and main storage batteries. Charging motor-generator in foreground, emergency engine-alternator set in background. Emergency lighting cabinet to left of control board.

rupter" which provides flashing or tone signals for "busy" and other uses and may provide half a dozen or more different signals. To the other end of this shaft is usually attached a ringing interrupter which divides the constant ringing current from the generator into machine ringing intervals such as 2 seconds ring, 4 seconds silent, or 1 second ring, 1 second silent, 1 second ring, and 3 seconds silent. This interrupter also controls battery current for tripping during the silent interval, and a "pickup" circuit the purpose of which is to prevent ringing the wrong party on party lines.

The generator and all the interrupters are regularly driven by an alternating-current line motor operating upon the outside power

supply. In addition to this, however, the set includes a direct-current motor designed to operate on current from the central office battery but normally not connected to the battery. Automatic relays and magnetic switches close the connection to the battery when the regular power fails so the set continues to operate without interruption

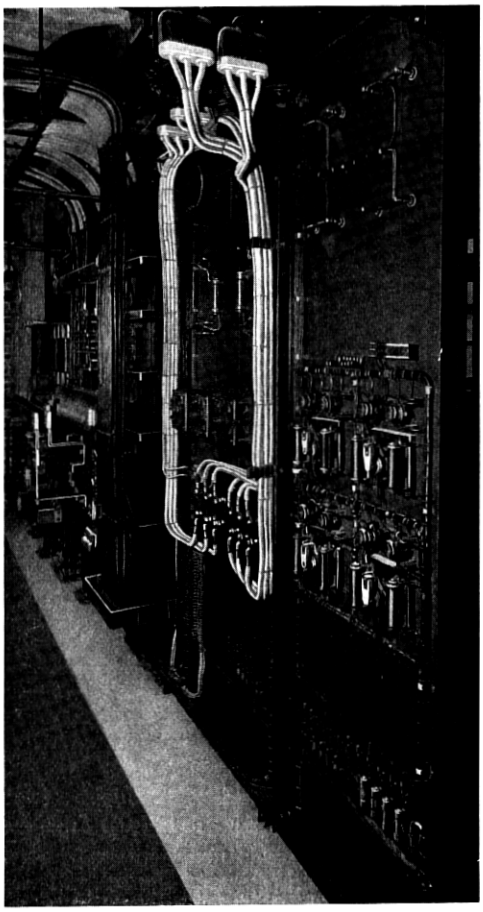

Fig. 12—Rear of control panel for charging sets and batteries.

or change in output. This feature avoids the delay of a few minutes which would otherwise result after a power failure, while the attendant started up a reserve motor-generator and transferred the load circuits, which may run from 17 circuits to twice that number for ringing, coin control, tones and signals. It also avoids accumulation of machine

ringing calls which occur when a ringing generator stops during a busy period and which may overload the motor sufficiently to blow the protective fuses and prevent restarting.

The battery motor is equipped with an automatic speed regulator which keeps the generator frequency within two per cent of rated speed throughout the range of the battery motor supply voltage.

It is obvious that a combination which will do so many things at once costs more than a simpler type of machine. The fact, however, that it will operate several central office units and will replace coin control batteries makes it cheaper than the equipment formerly required to do the work. With fewer machines and no batteries, except those for superimposing, installation is simplified. The closer voltage and speed regulation reduce relay and ringing troubles and, in conjunction with the continuity of operation, improve service from the subscribers' viewpoint, as well as reduce the amount of maintenance required of the attendants.

III. The Future Telephone Power Plant

It may be of interest to consider the direction toward which developments in prospect are leading, that we may learn what the future telephone power plant may be like. It seems probable that further progress will be made in the application of unit panels and unit

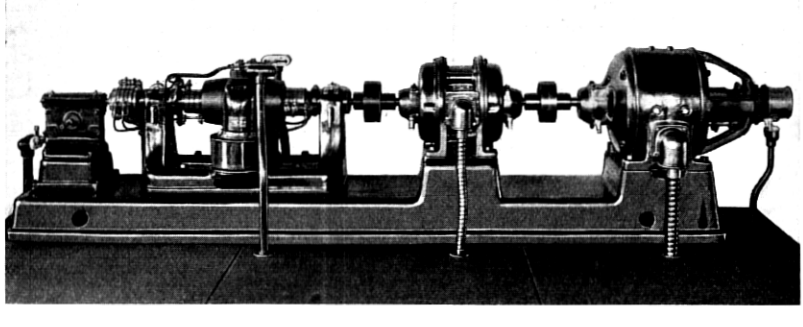

Fig. 13—One type of signaling machine—20-cycle ringing and direct-current 110-volt coin control machine, with reduction gearing for low-speed signals. Driven by a.-c. line motor with reserve battery motor automatically energized upon power failure. Speed controller on battery motor.

assembles or combinations of machines and control equipment. With the better characteristics, much of this equipment, including storage batteries, can be mounted with the circuit apparatus on standard racks, making self-contained units.

Because of the advantages to be obtained in circuit operation from closer voltage regulation and because of the higher cost of manual attendance, automatic regulators for machines and batteries will be used more extensively. Further attention will be given to the automatic operation of power plants, successfully accomplished for private branch exchanges and small offices.

Entirely automatic power plants for large offices could, it is believed, be developed without great difficulty somewhat along the lines of the automatic substations in use by some of the power and traction companies. These should, in general, require attention only periodically for cleaning, replacing worn parts, adjusting, etc., except during a failure of equipment or some other abnormal condition which would be indicated by an alarm. Since full automatic control would probably cost more than that requiring a limited amount of supervision, a study is required to determine how nearly automatic the equipment should be made for offices where an attendant will be required in any case for some of the equipment.

As for machines generally, the tendency will be towards greater use of more nearly commercial designs, construction and finish, eliminating as many as possible of the special features formerly necessary but not now required with changed conditions and the supplementary apparatus which recent developments have made available.

A more extended use of filters in power plant circuits may be expected.

In the direction of power supply, efforts have for some time been applied with some measure of success toward increasing the reliability of the service from outside, which work usually consists of cooperation with the electric supply companies in investigating conditions under which independent duplicate power services can be secured. The securing of reliable duplicate services permits elimination of a local emergency generating plant such as the engine-generator sets. As these efforts become more successful and the public service systems increase in extent and in reliability with the increase in interconnection, it should be found possible to reduce the amount of storage battery reserve in telephone power plants. Experimental introduction of low-voltage alternating-current networks similar to the direct-current networks used in the central parts of some large cities is being watched with interest and some installations are in progress. Although this might be classed as one electrical system, the safeguards against failure and the duplication of equipment is often such as to warrant entire dependence upon this power without a separate emergency source in the building.

With regard to types of batteries, the enclosed type in glass jars will be increasingly introduced wherever suitable because of the lower cost of installation and the subsequent reduced maintenance. The further extension of continuous floating systems of operation also makes it practicable in some cases to use batteries of the pasted plate construction in hard rubber jars, which are cheaper, particularly in first cost. On the general subject of battery operation, the use of the "continuous floating system" is being encouraged where practicable since this usually gives more efficient operation and always results in longer life for the storage batteries and in smaller sizes for equivalent reserve. As an alternate plan a "constant voltage charge system" is in process of adoption for general use where, for any reason, continuous floating is impossible or uneconomical.

The size and cost of power plants is largely controlled by the circuit and apparatus requirements, and improvements in these, such as reductions in current drains for dial equipment and for repeater tubes, are immediately reflected in the telephone power plant which will decrease in size and cost in almost direct proportion.