

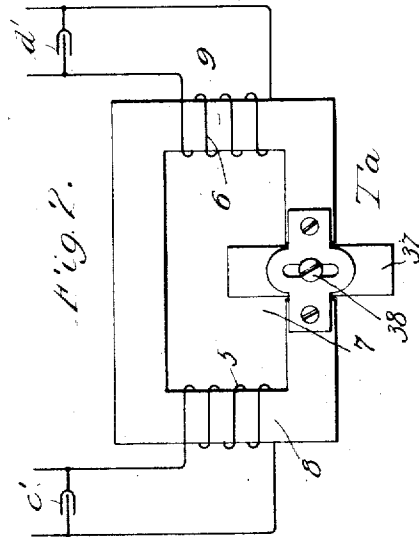
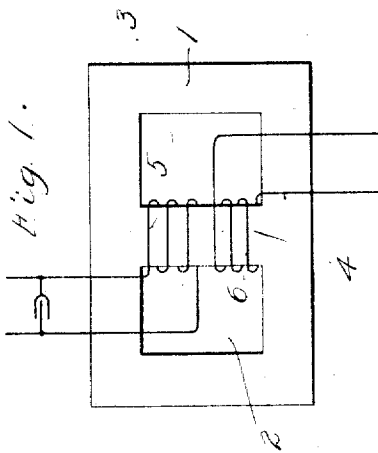
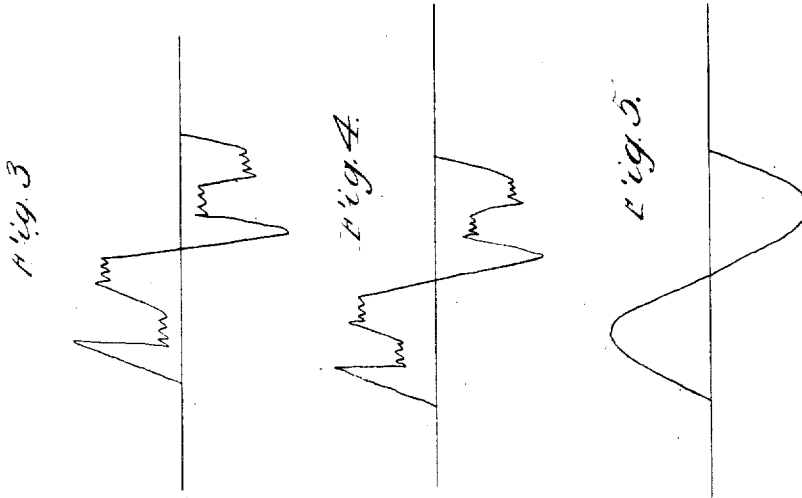
F. M. SLOUGH.
TRANSFORMER.

APPLICATION FILED SEPT. 11, 1907.

Patented Oct. 26, 1909.

2 SHEETS—SHEET 1.

937,877.



Witnesses:
Leonard W. Novander
George C. Higham.

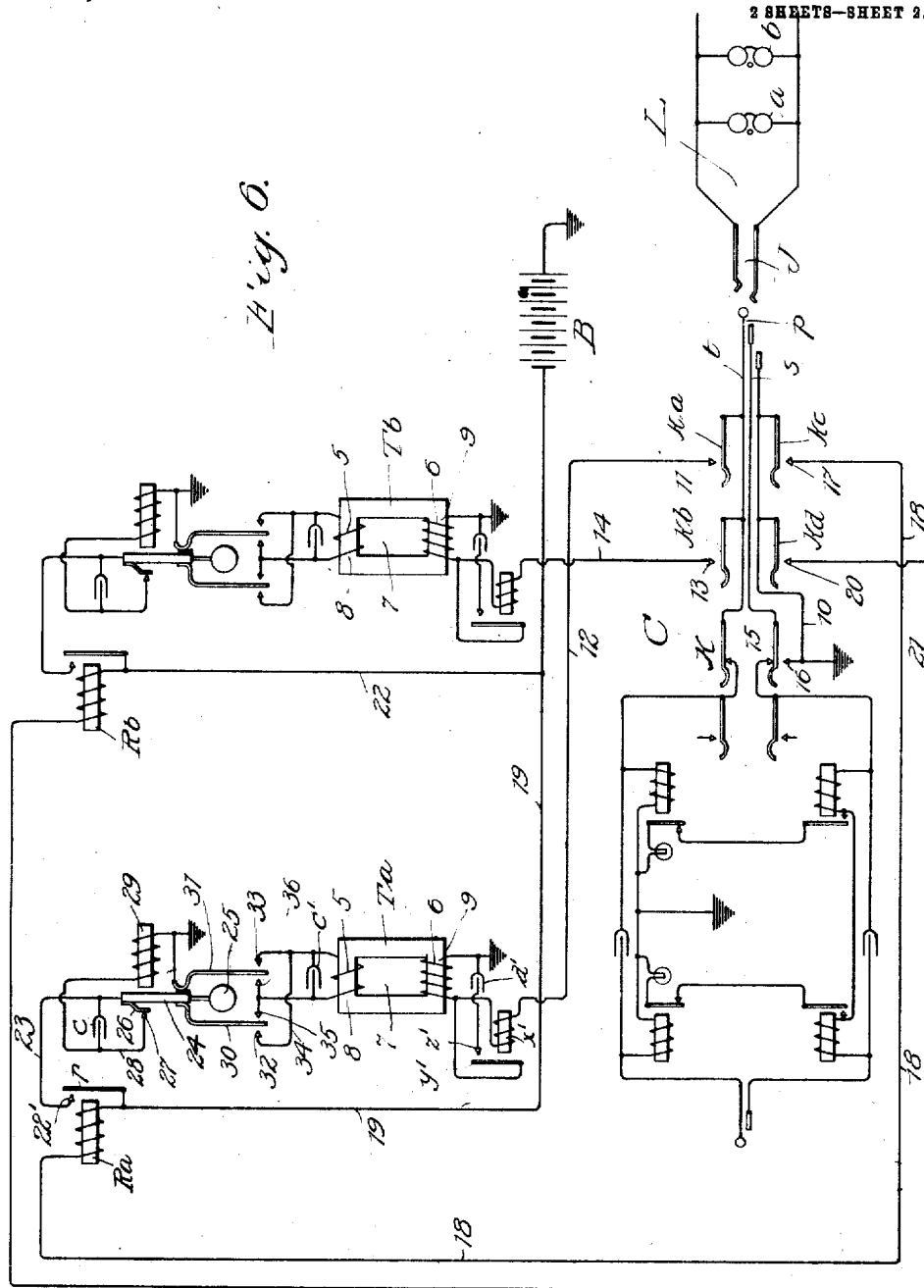
Inventor
Frank M. Slough
By Charles A. Brown
Attorney

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2 SHEETS—SHEET 2.



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Attorney

UNITED STATES PATENT OFFICE.

FRANK M. SLOUGH, OF ELYRIA, OHIO, ASSIGNOR TO DEAN ELECTRIC COMPANY, OF ELYRIA, OHIO, A CORPORATION OF OHIO.

TRANSFORMER.

937,877.

Specification of Letters Patent.

Patented Oct. 26, 1909.

Application filed September 11, 1907. Serial No. 392,263.

To all whom it may concern:

Be it known that I, FRANK M. SLOUGH, citizen of the United States, residing at Elyria, in the county of Lorain and State of Ohio, have invented a certain new and useful Improvement in Transformers, of which the following is a full, clear, concise, and exact description, reference being had to the accompanying drawings, forming a part of this specification.

My invention relates to telephone signaling systems, particularly to the ringing current producing mechanism therefor.

My invention is particularly adaptable to selective systems which employ harmonic converters or polarity changers for transforming direct current into alternating current, and in which transformers are used for transforming the produced alternating current into alternating current of proper voltage for ringing service. When these polarity changers are in operation, contacts are repeatedly opened and closed to cause alternating current flow through the primary winding of the transformer from a direct current battery, and to reduce or to prevent sparking at the contact points of the polarity changers, it is usual to connect a condenser across the primary winding. This use of the condenser together with the repeated opening and closing of the polarity changer contacts results in irregularities in the current produced in the secondary winding. The result is, instead of an efficient smooth sine wave current flow through the secondary winding and signaling circuit, the wave form of the secondary current is distorted. This irregular current flow manifests itself as disturbing noises in the telephone circuits whose conductors parallel the conductors conveying the secondary signaling current, these noises being particularly noticeable and disagreeable in the operator's telephone set.

The main purpose of my invention is to remedy these disturbing factors and to produce a current flow through the secondary winding which is in accordance with a smooth sine curve, and I accomplish this by an improved arrangement of the transformer magnetic circuit and windings and an improved arrangement of the condenser mechanism.

The usual arrangement of transformers is to place both the primary and secondary windings of the transformer on the same limb or section of the transformer core, the windings being usually superposed, the result being that whatever wave forms are produced in the primary winding are faithfully produced in the secondary winding together with all irregularities and disturbing elements.

In accordance with my invention, I separate the secondary winding from the primary winding to permit more or less magnetic leakage between such windings from the core of the transformer. The effect of this magnetic leakage upon the wave form of the electromotive force induced in the secondary winding is to smooth out the irregularities that would otherwise be caused by the irregular wave form of the electromotive force impressed upon the terminals of the primary winding, and to produce a wave form of electromotive force more nearly in accord with a sine wave.

It is particularly desirable in connection with telephone party-line signaling systems to use an electromotive force of sine wave form, since the apparatus which is best adapted for party line signaling for use at subscribers' stations is what is known as harmonic ringers, that is, ringers in which the vibrating part is tuned to respond only to a particular rate or frequency of alternating current when impressed upon such ringer. These ringers, it has been found, while they respond best to the exact frequency for which they are tuned, will also respond, but less effectively, for a slight variation either above or below the frequency for which they are designed. It has also been found that the range of responsiveness is less with an alternating current of sine wave form than with any other form of alternating current wave, and that this range of responsiveness is greatest with that form of alternating current wave in which the instantaneous value at the beginning of each cycle is very large compared with the remaining values during the cycle. Hence, in this work, it is very desirable to suppress the abnormally high values usually produced by polarity changers and to modify the wave form of the alternating current

supplied to the signaling circuit to as nearly a sine wave as possible. In this connection, it should be noted that the reluctance offered to the flow of magnetic flux by the core of the transformer is dependent largely upon the rate of change of the magneto motive force; that is, if the magnetizing current increases from a zero value to its maximum value in a comparatively small portion of the cycle, the reluctance offered to the magnetic flux is much greater proportionally than if the time interval were larger. This effect is due to the hysteresis and magnetic lag of the material of which the core is composed, and in my improved construction, I make use of this property to force a portion of the magnetic flux across the air gap between the two windings of the transformer from one portion of the core to another, and thus to cause, momentarily, an abnormal amount of magnetic leakage between such windings. In this way the induction in the secondary winding, which would result from the abnormally high value of the current at the start of the cycle, is avoided, and the effect is to produce an induced electromotive force in the secondary winding of nearly sine form.

In connection with polarity changers, it has been found desirable to bridge a condenser across the terminals of the primary winding to neutralize the sparking that would otherwise take place at the contacts on the polarity changer, and this condenser, I find, can be used to materially assist in modifying the form of wave of the impressed electromotive force. However, if depended upon alone to produce this effect, it would not be sufficient. I also find it desirable, under certain circumstances, to make use of a condenser bridged across the terminals of the secondary winding of the transformer, and find that by means of the arrangement of windings and condensers above described, when taken together, I am able to produce an electromotive force in the secondary winding of practically sine wave form. In this connection, it should be noted, however, that it is not practicable to use a condenser in connection with the secondary winding that will entirely produce this modification in wave form, since this would result in serious phase displacement and increased tendency toward sparking at the vibrator contacts in the primary circuit. I also provide means for normally disconnecting the condenser bridged across the secondary terminals from such secondary winding, when the transformer is not in use, as a result of which for no load conditions the current required by the primary winding of the transformer will not be excessive. I have also found it desirable to provide means for readily adjusting the air gap over which the above described magnetic leakage takes

place, in order that different conditions found in practice may readily be met by means of the same transformer.

The several drawings illustrating my invention are as follows:

Figure 1 illustrates the usual arrangement of windings and core in transformers; Fig. 2 shows an arrangement of these parts in accordance with my invention; Fig. 3 diagrammatically illustrates the curve of the electromotive force of the primary of the transformer of Fig. 1; Fig. 4 diagrammatically illustrates the electromotive force curve of the secondary of the transformer of Fig. 1; Fig. 5 represents the sine curve of the electromotive force and current of the secondary winding of the transformer in Fig. 2, and Fig. 6 diagrammatically illustrates a selective signaling system, showing the adaptation of my improved transformer.

Fig. 1 represents one of the usual transformers now used. The magnet core 1 is built up of rectangular laminations having the rectangular openings 2 and 3 cut therein to leave the central member 4 on which are mounted both the primary winding 5 and the secondary winding 6, usually superimposed upon each other, the coils being so close to each other that the magnetic flux caused by current now through the primary winding would also pass through the secondary winding, including the magnetic flow due to the superimposed irregularities, and the electromotive force and current curves in the secondary winding will be distorted as shown in Figs. 3 and 4, the wave forms shown being traced by means of the oscillograph and faithfully showing the exact behavior of electromotive force and current for the arrangement shown in Fig. 1. The superimposed irregular magnetic changes are very rapid in action and will follow the path of least resistance, and this path in the transformer shown in Fig. 1 will include the core surrounded by both windings. In Fig. 2, however, an improved arrangement in accordance with my invention is shown, the laminations being rectangular in form and having a central opening 7, the primary winding 5 encircling one limb 8 at the end of the core and the secondary winding 6 encircling the limb 9 at the other end of the core. Owing to this lengthening of the core and the relative location of the windings thereof, there is great increase in the magnetic reluctance of the core and a tendency for the magnetic flux to go in part between the windings from one portion of the core to the other, especially when the rate of change of the magneto motive force is rapid, and as a result the impressed electromotive force and current waves will be modified, for reasons already indicated, and will appear in the secondary winding in the form indicated in Fig. 5, that is, for this form of core and

relation of windings, the path of least reluctance for a portion of the magnetic flux will be from one part of the transformer core to another, and this path will lie between the windings of the transformer, as a result of which the extreme effect of the rapid change in the magneto motive force in the primary winding is avoided, and the wave forms of the current and electromotive force in the secondary winding are made to approximate a sine wave form.

In Fig. 6 a selective signaling circuit is shown, showing the adaptability of my improved transformer. The party telephone line *L* is shown as supplying two party substations represented by signal bells *a* and *b*, this line terminating at the central exchange *C* in spring jack *J*. The cord circuit at the central exchange comprises the tip and sleeve strands *t* and *s* respectively, terminating in the plug *p*. Connected with the tip strands are the key springs corresponding in number to the number of parties on the line—in this case, 2—and represented by *ka* and *kb*. The companion spring members *kc* and *kd* connect with a common grounded conductor 10. Contact 11 for key spring *ka* connects through conductor 12 with the secondary winding 6 of transformer *Ta*, while contact 13 for spring *kb* connects through conductor 14 with the secondary winding of transformer *Tb*, the other terminal of the transformer being grounded. Thus, if the first selective key is depressed, current generated in the secondary winding will flow through the following circuit; from the secondary winding of transformer *Ta*, through conductor 12 to contact 11, key spring *ka*, tip of plug *p*, through the spring jack and line *L*, through the signal bells *a* and *b*, through the sleeve side of the line and cord circuit, through spring 15 and contact 16 of the master key *K* to ground, and thence to the grounded terminal of the secondary winding of transformer *Ta*, this master key being actuated to disconnect the ringing key from the remainder of the cord circuit for well known reasons. For each transformer there is provided a polarity changer driven by direct current flow from a main battery *B* for transforming the direct current into alternating current flow through the primary winding of the transformer.

Each polarity changer is controlled by a relay *Ra*. Contact 17 for key spring *kc* connects through conductor 18 with one terminal of the relay whose other terminal connects through conductor 19 with one terminal of the battery *B* whose other terminal is grounded. In the same manner, contact 20 for spring *kd* connects through conductor 21 with one terminal of relay *Rb* whose other terminal connects through conductor 22 with the main battery. Thus, upon depression of the first selective key, current

will flow from battery *B* through conductor 19, relay *Ra*, conductor 18, contact 17, spring *kc* and through conductor 10 to ground and thence to the grounded terminal of the battery. Armature *r* of the relay *Ra* is connected with conductor 18, while its contact 22' connects through conductor 23 with the armature 24 of the polarity changer. Each armature carries a weight 25 which gages the rate of vibration of the armature and thus the frequency of the current produced. Contact 26 carried by armature 24 normally engages contact 27 connected through conductor 28 with one terminal of the winding of the electromagnet 29, the other terminal of this winding being grounded. Upon attraction of armature *r*, current flows from the main battery, through conductor 19, armature *r*, through conductor 23, contacts 26 and 27, conductor 28, and through electromagnet 29, causing attraction of armature 24 and disengagement of contacts 26 and 27. This disengagement of contacts 26 and 27 ruptures the circuit through electromagnet 29, and armature 24 being released, again engages contact 26 with contact 27 to cause closure of the circuit through electromagnet 29 and attraction of armature 24 to again disrupt the circuit, and so on, the result being vibration of armature 24 on the well known rheotome principle. Armature 24 carries a spring 30 having electrical contact therewith and a spring 31 insulated therefrom and connected with ground. The outer contacts 32 and 33 are associated with springs 30 and 31 respectively and are connected by conductors 34 which connects with one terminal of the primary winding of the transformer. The inner contacts 35 and 36 for the springs 30 and 31 are connected together and with the other terminal of the primary winding. Thus, when the armature is attracted, springs 30 and 31 will be carried into engagement with contacts 35 and 33 respectively, causing current flow from the battery through armature *r*, conductor 23, armature 24, spring 30, contact 35, primary winding, contact 33, and spring 31 to ground, the current flow being through the primary winding in one direction. Upon release of the armature springs 30 and 31 are thrown against contacts 32 and 36 respectively, and current flowing to armature 24 flows through spring 30, contact 32, conductor 34, primary winding, contact 36, and spring 31 to ground, the direction of current flow through the primary winding being in the opposite direction, and thus upon vibration of the armature 24, alternating current flow will be produced through the primary winding which will be induced into the secondary winding. A suitable condenser *c* is usually bridged across contacts 26 and 27 to prevent sparking, and also to prevent sparking at

the polarity changer contacts a condenser c' is usually employed bridged between the primary terminals.

The combination of my improved transformer arrangement and the condenser c' tends to eliminate all irregular and disturbing elements from the secondary circuit and to produce current flow along a smooth sine curve which form of current flow is best adapted and safest for uses in selective signaling systems. As the polarity changers are during the greater part of the time under no load conditions, the condenser c is preferably designed to prevent sparking at the polarity changer contacts under such no load conditions. When, however, current flows through the secondary winding and circuit, the condenser is no longer able to suppress all the sparking, and I find that sparking can be entirely prevented under working conditions by bridging a condenser d' about the secondary winding. I find that the use of this condenser across the secondary winding also assists in smoothing out the wave form and through which reaction on the primary circuit of the transformer greatly improves the operation of the polarity changer or converter.

One of the advantages of a condenser across the secondary circuit is to take up the high voltage discharges due to the rapid drop in magnetization when the circuit in the primary is abruptly opened. These high voltage discharges, unless suppressed, are sufficient under certain circumstances to puncture the insulation of the switchboard conductors and other apparatus connected with the ringing circuit. The condenser d' should, however, be carefully adjusted. Where the secondary current used is not very heavy, a condenser of small capacity could be used and could be bridged directly across the secondary terminals without seriously influencing the operation of the converter under no load conditions.

When the current in the secondary circuit is to be heavy, a larger capacity condenser, of course, must be used across the secondary in order to suppress the sparking at the converter contacts, and if the condenser were bridged directly across the secondary winding, a heavy load would be placed on the primary winding under no load conditions. It is, therefore, preferable, when a large capacity condenser is used, to provide for disconnecting the condenser from circuit under no load conditions. One way of accomplishing this would be to include the windings of a relay x' in the secondary circuit of the transformer, the connection of one terminal of the condenser d' with the secondary winding being controlled by the armature y' and contact z' of the relay. Normally the condenser circuit is open, but upon depression of a ringing key, the secondary

circuit is closed, and current flow through the relay causes attraction of its armature and closure of the condenser circuit, the condenser d' then becoming effective. The relay used in this case should preferably be of the slow acting type, in order that it may not be vibrated by the alternating current in the secondary circuit and thereby cause arcing at the contact z' . Other ways, of course, could be readily devised for causing the secondary condenser to be effective only when signaling current is to be used. In an arrangement like this there will be no sparking at the converter contacts under no load conditions nor under operating conditions when ringing current is being used, and the condensers and the transformer winding arrangement mutually assist each other to prevent such sparking and to improve the action of the transformer to give the proper form of alternating current wave.

As shown in Fig. 2, I provide means for varying the amount of magnetic leakage above described, which I have found desirable to meet the various conditions found in practice, so that the same design transformer may be used to meet these different conditions. This consists, as indicated, in providing an adjustable member 37 in one limb of the transformer by means of which the air-gap in the leakage path may be increased or decreased, as desired. A clamping screw 38 is provided to secure the member 37 in any desired adjustment.

Having described my invention, I desire to secure by Letters Patent the following claims:

1. In a signaling system, in combination with suitable signal receiving apparatus, a source of signaling current, a polarity changer connected to such source of current, a transformer having primary and secondary windings, such polarity changer adapted to intermittently supply current from such source to such primary winding, such secondary winding connected to such signal receiving apparatus, and means for automatically including reactive means in circuit with the secondary winding when current is delivered from such secondary winding.
2. In a signaling system, in combination with suitable signal receiving apparatus, a source of signaling current, a polarity changer connected to such source of current, a transformer having primary and secondary windings, such polarity changer adapted to intermittently supply current from such source to such primary winding, such secondary winding connected to such signal receiving apparatus, and means for automatically including reactive means in circuit with the secondary winding when the current flowing in the secondary winding reaches a predetermined strength.
3. In a signaling system, in combination

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- with suitable signal receiving apparatus, a source of signaling current, a polarity changer connected to such source of current, a transformer having primary and secondary windings, such polarity changer adapted to intermittently supply current from such source to such primary winding, such secondary winding connected to such signal receiving apparatus, reactive means normally disconnected from such secondary winding, and means for automatically including such reactive means in circuit with the secondary winding when current is delivered therefrom.
- 15 4. In a signaling system, in combination with suitable signal receiving apparatus, a source of signaling current, a polarity changer connected to such source of current, a transformer having primary and secondary windings, such polarity changer adapted to intermittently supply current from such source to such primary winding, such secondary winding connected to such signal receiving apparatus, reactive means normally disconnected from such secondary winding, and means for automatically including such reactive means in circuit with the secondary winding when the current flowing in such secondary winding reaches a predetermined strength.
- 30 5. In a signaling system, in combination with suitable signal receiving apparatus, a source of signaling current, a polarity changer connected to such source of current, a transformer having primary and secondary windings, such polarity changer adapted to intermittently supply current from such source to such primary winding, such secondary winding connected to such signal-receiving apparatus, a condenser normally disconnected from such secondary winding and means for automatically connecting such condenser across the terminals of such secondary winding when current is delivered therefrom.
- 45 6. In a signaling system, in combination with suitable signal receiving apparatus, a source of signaling current, a polarity changer connected to such source of current, a transformer having primary and secondary windings, such polarity changer adapted to intermittently supply current from such source to such primary winding, such secondary winding connected to such signal receiving apparatus, a condenser normally disconnected from such secondary winding, and a relay connected with such secondary winding adapted to automatically connect such condenser across the terminals of such secondary winding when current is delivered therefrom.
- 60 7. In a telephone system, a central office, line wires extending therefrom to a subscriber's station, signal receiving apparatus at such subscriber's station, a source of signaling current at such central office, a polarity changer connected to such source of current, a transformer having primary and secondary windings, such polarity changer adapted to supply current from such source periodically in reversed directions to such primary winding, means for inducing an electromotive force of practically sine wave form in such secondary winding comprising in part a condenser normally disconnected from such secondary winding and adapted to be automatically connected to the terminals of such winding when current is delivered therefrom, and means for supplying the current induced in such secondary winding to such line wires.
8. In a telephone system, a central office, line wires extending therefrom to a subscriber's station, signal receiving apparatus at such subscriber's station, a source of signaling current at such central office, a polarity changer connected to such source of current, a transformer having primary and secondary windings, such polarity changer adapted to supply current from such source periodically in reversed directions to such primary winding, means for inducing an electromotive force of practically sine wave form in such secondary winding comprising in part a condenser normally disconnected from such secondary winding and adapted to be automatically connected to the terminals of such winding when current is delivered therefrom, a second condenser connected across the terminals of the primary winding of such transformer and in so locating the windings on such transformer as to permit magnetic leakage between them, and means for supplying the current induced in such secondary winding to such line wires.
9. In a telephone system, a central office, line wires extending therefrom to a subscriber's station, signal receiving apparatus at such subscriber's station, a source of signaling current at such central office, a polarity changer connected to such source of current, a transformer having primary and secondary windings, such polarity changer adapted to supply current from such source periodically in reversed directions to such primary winding, means for inducing an electromotive force of practically sine wave form in such secondary winding comprising in part a condenser normally disconnected from such secondary winding and a relay in circuit with such secondary winding adapted to automatically connect such condenser to the terminals of such winding when current is delivered therefrom, and means for supplying the current induced in such secondary winding to such line wires.
10. In a telephone system, a central office, line wires extending therefrom to a subscriber's station, signal receiving apparatus

at such subscriber's station, a source of signaling current at such central office, a polarity changer connected to such source of current, a transformer having primary and secondary windings, such polarity changer adapted to supply current from such source periodically in reversed directions to such primary winding, means for inducing an electromotive force of practically sine wave form in such secondary winding comprising in part a condenser normally disconnected from such secondary winding and a relay in circuit with such secondary winding adapted to automatically connect such condenser to the terminals of such winding

when current is delivered therefrom, a second condenser connected across the terminals of the primary winding of such transformer and in so locating the winding on such transformer as to permit magnetic leakage between them, and means for supplying the current induced in such secondary winding to such line wires.

In witness whereof, I hereunto subscribe my name this 22nd day of August A. D., 1907.

FRANK M. SLOUGH.

Witnesses:

RAY H. MANSON,
GEO. A. SCOVILLE.