Aug. 13, 1929. M. L. SINDEBAND ET AL 1,724,112

COMMUNICATING SYSTEM FOR POWER TRANSMISSION LINES

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Fig. 1

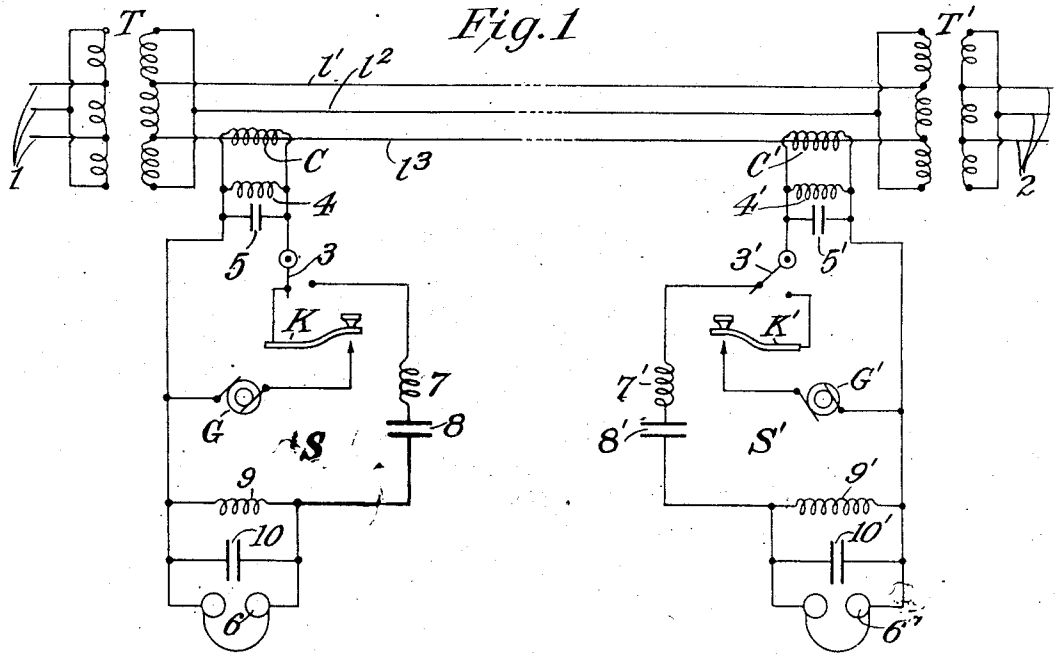


Fig. 2

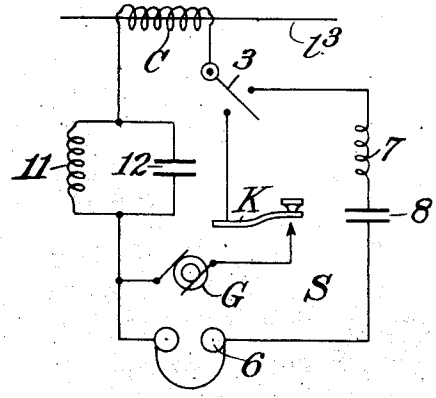
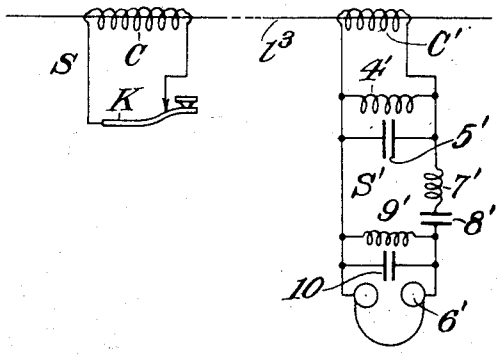


Fig. 3



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Fig. 4

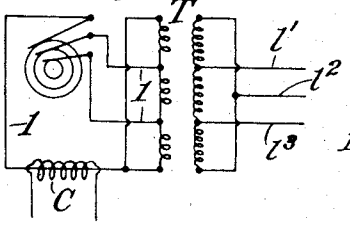


Fig. 5

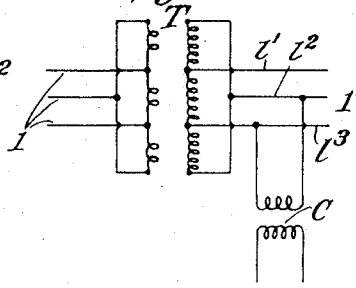


Fig. 6

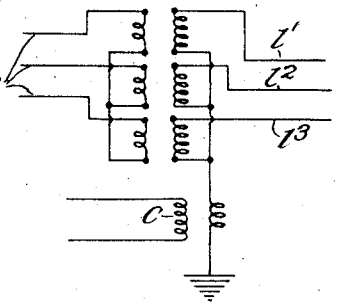


Fig. 7

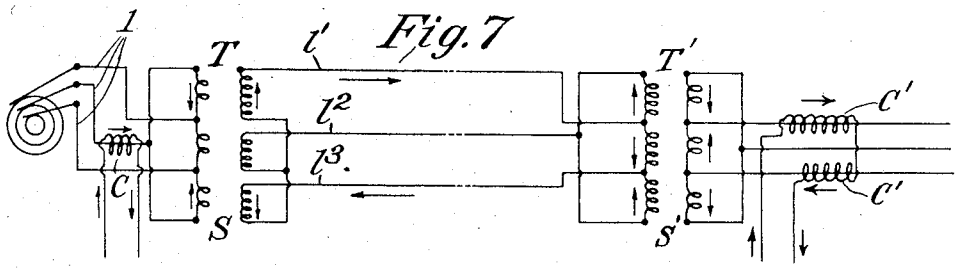


Fig. 8

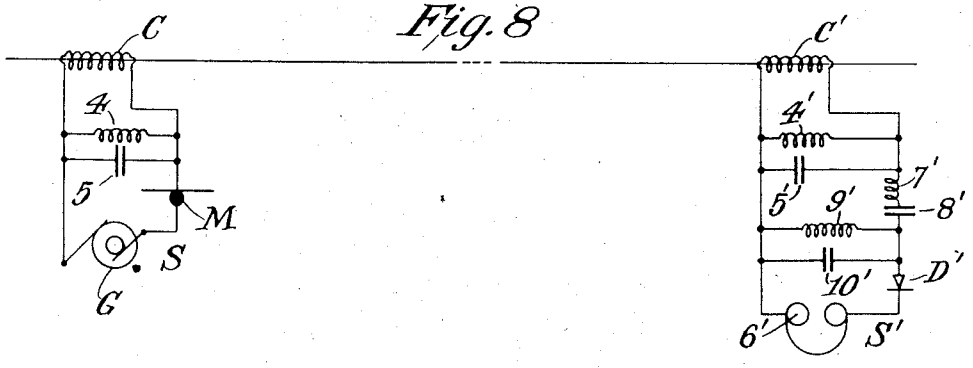


Fig. 9

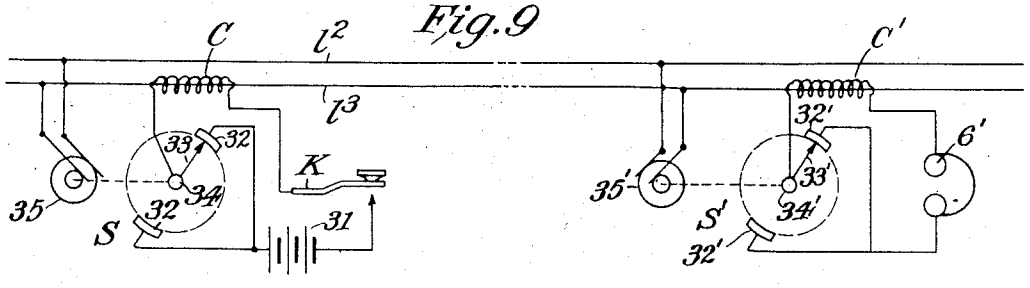
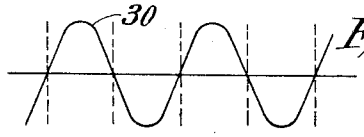


Fig. 10



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COMMUNICATING SYSTEM FOR POWER TRANSMISSION LINES

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Fig. 11

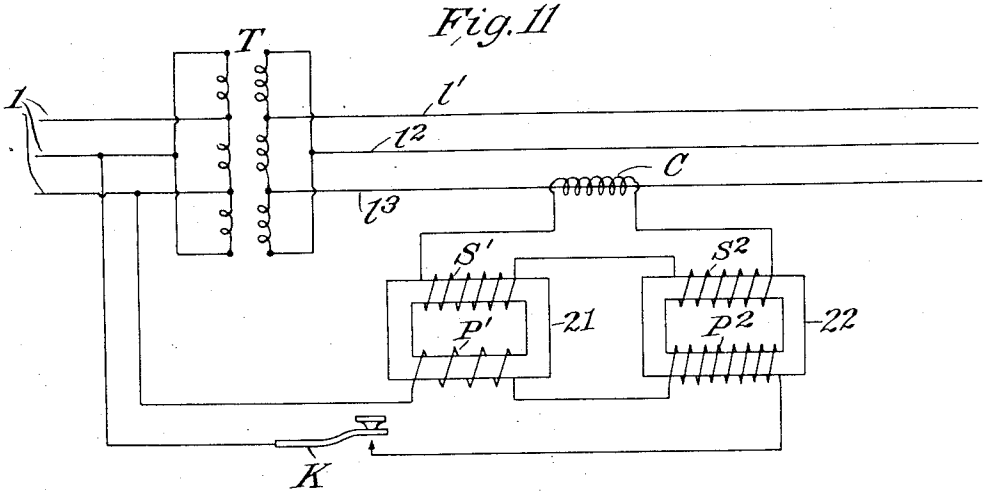


Fig. 12

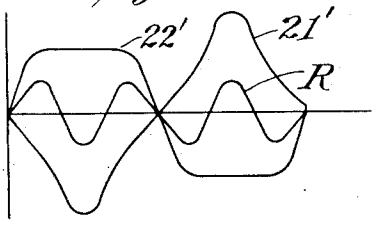
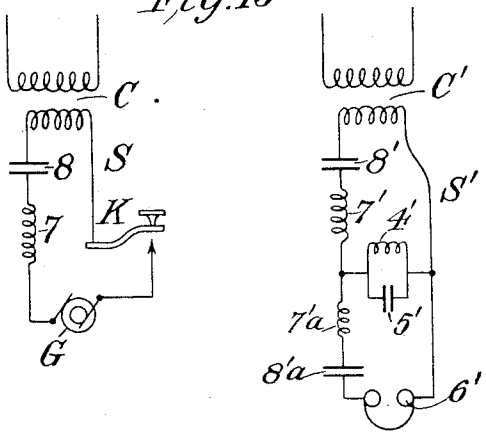


Fig. 13



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UNITED STATES PATENT OFFICE.

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COMMUNICATING SYSTEM FOR POWER-TRANSMISSION LINES.

Application filed January 28, 1920, Serial No. 354,602. Renewed December 18, 1928.

This invention relates to systems for conveying intelligence. More specifically it relates to systems for telephoning or telegraphing over a line employed to transmit power.

Alternating current transmission lines have long since been employed, and are coming into more general use, to transmit power to points distant from the source of power. In order properly to operate these systems and to render them effective it is desirable that some form of reliable, private, communicating system, such as the telephone or telegraph, be provided between the power supply station and the consuming station or stations. The desirability or necessity for such a communication is emphasized by the now common interchange contracts entered into between various companies operating plants and interconnected transmission lines. In the past it has been the practice to install telephone or telegraph wires on the same poles or towers which support the high tension power wires or conductors. This method is open to objection because of the cost of the signal line wire. But a still greater objection exists due to the inductive disturbances set up in the signaling conductors due to the proximity of the power conductors. The last mentioned objection may be more or less overcome by mounting the signaling conductors on separate poles spaced from those which support the power lines. However, this method increases the installation and maintenance costs still more.

One of the principal objects of the present invention is to provide a novel form of land line, signaling or communicating system in which no line wires other than the power transmission conductors are required and in which there is practically no disturbance, inductive or otherwise, between the power transmitting and signalling systems. Other objects and advantages will appear as the invention is hereinafter disclosed.

Referring to the drawings which illustrate what we now consider preferred forms of our invention:

Fig. 1 is a diagrammatic view illustrating one form of telegraph system embodying our invention.

Fig. 2 is a wiring diagram of a modified combined sending and receiving station.

Fig. 3 is a diagram illustrating a different means for superimposing the signaling current upon the power current.

Figs. 4, 5, 6 and 7 are diagrams illustrating some of the different ways of coupling the local signal circuits to the power transmission system.

Fig. 8 is a wiring diagram illustrating our invention adapted for telephonic communication.

Fig. 9 is a modified form of telegraph system.

Fig. 10 is a diagram utilized in explaining the theory of operation of the system shown in Fig. 9.

Fig. 11 illustrates diagramatically, a form of transmitting means, different from that in Fig. 3, for superimposing upon the transmission line a frequency three times that of the power current.

Fig. 12 is a diagram employed in explaining the theory of operation of the means shown in Fig. 11.

Fig. 13 illustrates a system somewhat similar to that in Fig. 1, but slightly modified.

While the invention it applicable to an alternating current transmission line of any number of phases we have shown it applied to a three-phase system. In Fig. 1 the power is adapted to be supplied to the line through the conductors 1 (supplied by a suitable generator, not shown) and a step-up transformer T. The primary and secondary of the latter are both shown delta connected and the three-phase, three-wire line is indicated at l^1, l^2, l^3. The other end of the line is shown connected to the primary of a step-down transformer T', the secondary of which is connected to lines 2 which go to the load. The system thus far described is one commonly employed for high tension transmission.

We employ the power conveying line as the signaling line by suitably coupling transmitting means at at least one station and receiving means at the other station or preferably both stations. Thus at station S we have shown a generator G of alternating current of a frequency different from that of the frequency of the current supplied to

the line l^1—l^3. For example, if the power frequency is 60 cycles per second the frequency of the generator G may be 400 cycles. The generator G is shown connected to and controlled by a key K and coupled to one phase l^3 of the line by means of a current transformer of which one winding is designated C. Obviously, with the switch 3 in the position shown at station S, depression of the key K will cause the generator G to supply current to the transmission line at a frequency equal to that for which said generator is designed, or in the example above, 400 cycles. In order substantially to prevent the power current (assumed to be at 60 cycles) from reacting on the circuit G, K, the means shown at 4, 5 in Fig. 1 may be employed. It will be seen that the inductance 4 and capacity 5 are connected in parallel across the winding C and these impedances are designed or adjusted for parallel resonance; i. e., to be antiresonant, at the frequency of the generator G. This means that with the values of frequencies above assumed the combined impedance offered to the signal current at 400 cycles by the elements 4, 5 will be practically infinite although the impedance offered by the last mentioned elements to the passage of the power current will be comparatively low. This means that so far as the passage of signaling current in the circuit G, K, C is concerned the set 4—5 is substantially of no effect. On the other hand, practically all of the lower frequency current, introduced into the local circuit by the winding C, passes through the elements 4—5 by virtue of the comparatively low impedance of the latter at the power frequency.

The receiving means at the station S′ is shown as comprising a current transformer C′, inductance 4′ and capacity 5′ in all respects similar to the corresponding elements C, 4 and 5 at the station S. With the switch 3′ in the position shown it will be seen that the coil or winding C′ is in series with a telephone receiver, or other receiving device, 6′ and inductance and capacity 9′ and 10′ designed for parallel resonance at the frequency of the generator G may be shunted across the receiver 6′ for the purpose of shunting out any power frequency current which may pass the anti-resonant set 4′, 5′. The impedances 7′ 8′ are preferably so designed or adjusted that the receiving circuit containing the receiver 6′ will be tuned to, or resonant at, the frequency of the generator G, whereby a maximum amount of signaling current will flow through the receiver 6′. The impedances 7′, 8′ are also preferably designed or adjusted for series resonance at the signaling frequency. With such design the combined impedance 7′—8′ will materially restrict the flow of any power frequency current which may pass the set 4′—5′. While we have described a sending means at the station S and receiving means at station S′ it is preferable, of course, to provide both a sending means and receiving means at each station. We have shown such a system in Fig. 1, the elements K′ and G′ at station S′ corresponding to elements K and G at station S and elements 6, 7, 8, 9 and 10 at station S corresponding to elements 6′, 7′, 8′, 9′ and 10′ at station S′. In short the signaling equipment at one station is identical to that at the other.

To understand the operation of the system above described, let it be assumed that the line l^1, l^2, l^3 is carrying current at 60 cycles and that both switches 3, 3′ are in the receiving position. If the operator at station S desires to communicate with the operator at the station S′ the former need only start his generator G through switch 3 to sending position and then manipulate the key K in the usual manner. The receiving circuit at S′ being tuned to the frequency of the generator G, the operator at S′ will be able to read the message by means of the instrument 6′. Due to the shunts 4′—5′ and 9′—10′, as well as the impedance offered to the power current by the elements 7′, 8′, the receiver 6′ will be free from any noise which would otherwise be caused by the power current. Signalling from station S′ may be accomplished in a similar manner.

The system above described may be modified in various respects. Thus, instead of relying on the elements 4, 5, 4′, 5′, 9, 10, 9′, and 10′ to restrict or substantially eliminate the flow of power current in the local signalling circuits, some or all of these elements may be omitted and the arrangement shown in Fig. 2 adopted. In this figure, which depicts the apparatus at one station (the apparatus at the other station being identical), the elements K, G, C, l^3, 3, 6, 7 and 8 will at once be recognized in view of the explanation of Fig. 1. The anti-resonant sets 4—5, 4′—5′, 9—10 and 9′—10′ are all omitted and inductance 11 and capacity 12 substituted therefor. The inductance 11 and capacity 12 are connected in parallel with each other and are either in series with the generator G or receiver 6 depending on the position of the switch 3. The set 11—12 is designed for parallel resonance at the frequency of the power current i. e. the set 11—12 will offer substantially infinite impedance to any flow of power current in the sending or receiving circuits but will offer comparatively little impedance to the flow of the signalling current.

Instead of employing a separate generator G, or G′ for superimposing a signalling frequency on the power transmission line the arrangement shown in Fig. 3 may be adapted. To simplify the explanation we have omitted the receiving means at the station

S and the sending or transmitting means at the station S'. The key K in this form of the invention is normally closed, i. e., its back contacts are connected across the winding C of the current transformer. The design is such that when the key K is in the normally closed position, a moderate current flows through the winding C of the current transformer and the power currents are transmitted over the transmission line in the usual and normal manner. But when the key K is depressed the circuit including winding C is opened and the current in the other winding (primary) of the current transformer then causes the ferrous magnetic circuit (not shown) of the current transformer to become greatly over-saturated. This introduction of impedance in the power line l^3 distorts the shape of the wave of the power current and introduces higher harmonics into the transmission line. Suppose that the frequency of the power current is 60 cycles and the design of the transmitting means is such that, on depression of the key K, a third harmonic is introduced into the transmission line. The sets 4'—5' and 9'—10' should then be tuned to be anti-resonant to a frequency of 3×60 i. e. 180 cycles, and the circuit containing the receiver 6' should be designed to be resonant at the last mentioned frequency. The receiver 6' will then respond to the third harmonic but will be substantially unaffected by the fundamental of the power current wave. In other words the receiver 6' will respond every time the key K is depressed.

A still different means for impressing a signalling current of a different frequency upon the line is shown in Fig. 11. Two transformers 21 and 22 are provided. When the normally open key K is closed current at the power frequency f is supplied to the primaries P^1 and P^2 in series. The primary P^1 has comparatively few turns and the primary P^2 many turns so that the iron is magnetized more intensely in 22 than in 21. The two secondaries S^1 and S^2 are so wound and connected that the E. M. F.'s of the fundamental frequenty neutralize each other, but the third harmonics cause a current flow in the coil C at a frequency $3f$. This may be more readily understood by referring to Fig. 12 in which the curve 22' represents the E. M. F. in the secondary S^2, the curve 21' that in secondary S^1 and curve R the resultant triple frequency E. M. F. in the coil C. Any of the three types of receiving circuits shown in Figs. 1, 2 or 3 may be employed with the transmitting means shown in Fig. 11.

Various modifications in the method of coupling the sending and receiving circuits to power transmission line may be resorted to. Thus instead of coupling the current transformers C and C' to the high tension line they may be coupled to the low tension side as indicated at C in Fig. 4. Or, instead of employing current transformers, potential transformers may be employed. Thus in Fig. 5 one winding of the transformer is connected across phase 1^2—1^3 on the high tension line, the other winding being indicated at C. A further modification is illustrated in Fig. 6 in which the primary and secondary of the transformer T are Y connected, the transformer C having one of its windings inserted in the lead which connects the neutral point of the secondary of the transformer to ground.

In Fig. 7 we illustrate a further modification in the manner of coupling the signalling circuits to the power transmission system. In this figure the primary of the transformer T is delta connected while the secondary is Y connected. The primary of the transformer T' is delta connected as is also the secondary thereof. The signalling set at the station S is coupled to the power transmission system by means of a current transformer in one of the low tension phases of the transformer T. The signalling set at the station S' is coupled to the power transmission system by means of two current transformers C', C', one connected in one of low tension phases of the transformers T' and the other in another low tension phase of said transformer T'. The relative direction of flow of the signalling may be seen by inspection of Fig. 7 in which the arrows indicate direction of flow at a particular instant.

The disclosure, up to this point, has been restricted to telegraphic systems, i. e., systems in which the frequency of the signalling current is between 400 and 4000 cycles per second. At least some, if not all of the system thus far described may be utilized, by employment of proper sending and receiving instruments, for telephonic communication. In this case a signalling frequency of 5000 cycles per second, or upwards thereof, is preferably employed. To avoid unnecessary surplusage we show but one adaptation of the invention to telephonic communication and in this illustration the receiving set is omitted from one station and the sending or transmitting set from the other for the sake of simplification. Referring to Fig. 8, the similarity between the most of the elements there shown and the corresponding elements in Fig. 1 will at once be apparent. The generator G, in this case, preferably has a frequency of at least 5000 cycles and the key K is replaced by a microphone or telephone transmitter M. It will also be noted that the telephone receiver 6' has connected in series therewith a crystal detector or other suitable rectifier D'. This modification of our invention is disclosed and claimed in our copending

application, Serial No. 235,430, filed November 25, 1927, which is a division of this application.

In operation the operator at station S speaks into the device M thus modulating the high frequency current and the sound vibrations will be reproduced at 6′ as will be apparent to those skilled in the art in view of the above disclosure.

From the above description of our invention it will be appreciated that we have provided communicating systems in which the power-conveying conductors alone are employed to convey the signalling current without any substantial interference with the power transmission. No line wires other than the power lines are required so that the installation as well as maintenance costs are minimized. Furthermore, by virtue of the sets 4—5, 4′—5′, 9—10 and 9′—10′ which are designed or adjusted for parallel or anti-resonance at the signalling frequency employed or the sets 11—12 designed for parallel resonance at the power frequency; there is practically no noise caused in the receiving instrument by the low frequency power current.

A system specially different but from a generic standpoint in many respects the same as those already described, is illustrated in Fig. 9. Before describing this system in detail, we wish to explain the theory upon which it is based. The curve 30 in Fig. 10 represents the power current in the line wire l^3. It will be noted that this current passes through zero twice in each cycle. In other words there are $2f$ (where f is the power frequency in cycles per second) intervals per second in which the line l^3 is dead and may be employed to convey signalling current. Furthermore, if means are provided to render the signalling circuits operative only when the power current is substantially zero, the last mentioned current will be substantially prevented from flowing to the signalling instruments. One form of means for accomplishing these functions is indicated diagrammatically in Fig. 9. Here again for the sake of simplicity we show only one transmitting means and one receiver. The elements 1^2, 1^3, C, C′ and K will at once be recognized. The key K is connected in series with the winding C of the current transformer, a battery 31 and a circuit controller. The last mentioned device comprises one or more contact segments 32 adapted to be engaged by a contact arm 33 mounted on a shaft 34. The shaft 34 is driven by a synchronous motor 35 supplied from the power line by any suitable connections. The design and adjustment of the contacts 32—33 is such that current cannot flow through the said contacts except when the power current in line l^3 is substantially zero and then only if the key K is closed. It will therefore be understood that when the key K is closed unidirectional current impulses will pass through the winding C at a rate of $2f$ per second, each impulse occurring at a time when the power current is zero. The receiving system shown at S′ is a duplicate of the system shown at S except that battery 31 and key K are omitted and receiving instrument 6′ substituted therefor.

In operation, when the key K is closed the receiver 6′ will receive current impulses at the rate of $2f$ per second and a comparatively loud note of this pitch will be emitted thereby. When the key is open no signaling current is transmitted and as the contacts 32′—33′ are designed to close only when the E. M. F. induced in the coil C′ by the power current is substantially zero, there will be practically no sound in said receiver at this time.

In Fig. 13 we have illustrated a system in which the set 4, 5 is omitted in the sending circuit, the set 7, 8 being designed or adjusted for series resonance at the signalling frequency. This arrangement is particularly adapted to the form of the invention in which the transformers C, C′ are potential transformers. The set 7′—8′ and $7^{a\prime}$—$8^{a\prime}$ in the receiving circuit are each designed or adjusted for series resonance at the signalling frequency and the set 4′—5′ for parallel resonance at the same frequency. The operation of this form of the invention will be understood in view of the explanation in connection with the preceding figures.

It will be understood that the specific physical embodiments herein disclosed are illustrated only diagrammatically and to avoid confusion and surplusage more or less auxiliary apparatus such as manually operable switches, discharge resistances, blocking condensers etc., which may prove desirable in practice, have been omitted. However, with the present disclosure before him a man skilled in the art could make and use the invention. It is to be borne in mind also that while it is at present preferred to employ the various features and elements in the combinations described, some of these may be altered and others omitted and some of the features of each modification may be embodied in the others without interfering with the more general results and effects outlined and the invention extends to such use.

What we claim is:

1. A signalling system comprising in combination, a power transmission line adapted to conduct alternating current at a predetermined fundamental frequency, means energized from said power transmission line

for setting up a harmonic of said fundamental frequency in said line at will, receiving means responsive to said harmonic, and means for substantially preventing flow of current at said fundamental frequency through the receiving means.

2. A combined power and intelligence conveying system comprising in combination, a multi-phase power generator, a step-up transformer whose primary is delta connected to said generator, a power transmission line to which the secondary of said transformer is Y-connected, a step-down transformer delta connected to said line and whose secondary is delta connected, a signalling circuit coupled to said power system by means of a current transformer in one of the low tension phases of one of said two first named transformers, and a signalling circuit coupled to said power system by means of two current transformers each connected in a different one of the low tension phases of the other of said two first named transformers.

3. A combined power and intelligence conveying system comprising in combination a multi-phase power generator, a multi-phase transformer whose primary winding is connected to said generator, a multi-phase transmission line to which the secondary of said transformer is connected, a signaling circuit coupled to said power system by means of a current transformer in one of the phases of said primary winding, and a second signaling circuit coupled to said multi-phase transmission system by means of two current transformers each connected to a different phase of said system.

4. A combined power and intelligence conveying system comprising in combination a multi-phase source of current supply, a transformer whose primary winding is delta-connected to said source, a power transmission line to which the secondary of said transformer is Y-connected, a second transformer delta-connected to said line and whose secondary winding is delta-connected, a signaling circuit coupled to said power system by means of a current transformer in one of the phases of the primary of said first mentioned transformer, and a signaling circuit coupled to said power system by means of two current transformers each connected to a different one of the phases of the secondary of said second mentioned transformer.

In testimony whereof we hereunto affix our signatures.

MAURICE L. SINDEBAND.
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JOSEPH W. MILNOR.