

Sept. 8, 1942.

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2,294,905

POWER LINE TELEPHONE SYSTEM

Filed April 19, 1941

3 Sheets-Sheet 1

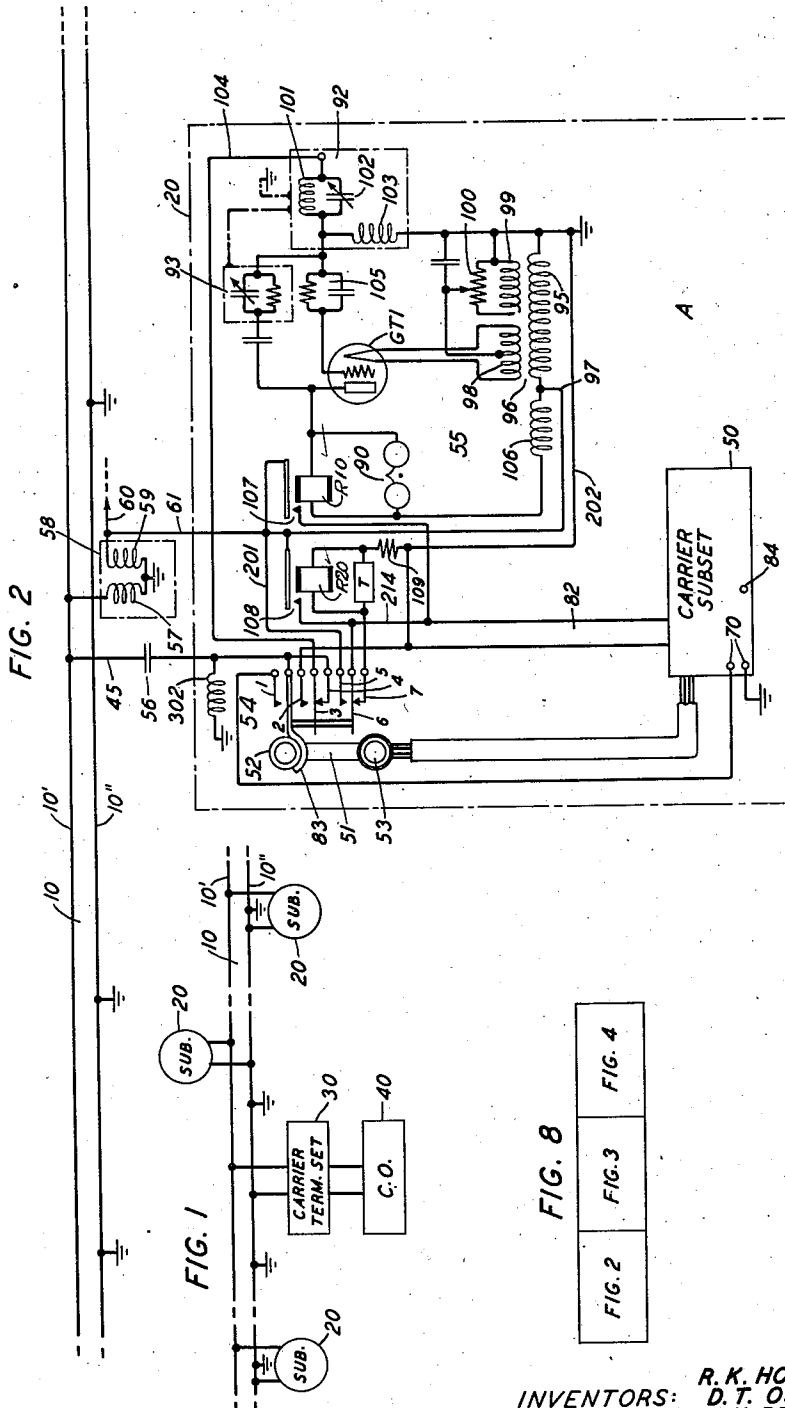


FIG. 8

FIG. 2	FIG. 3	FIG. 4
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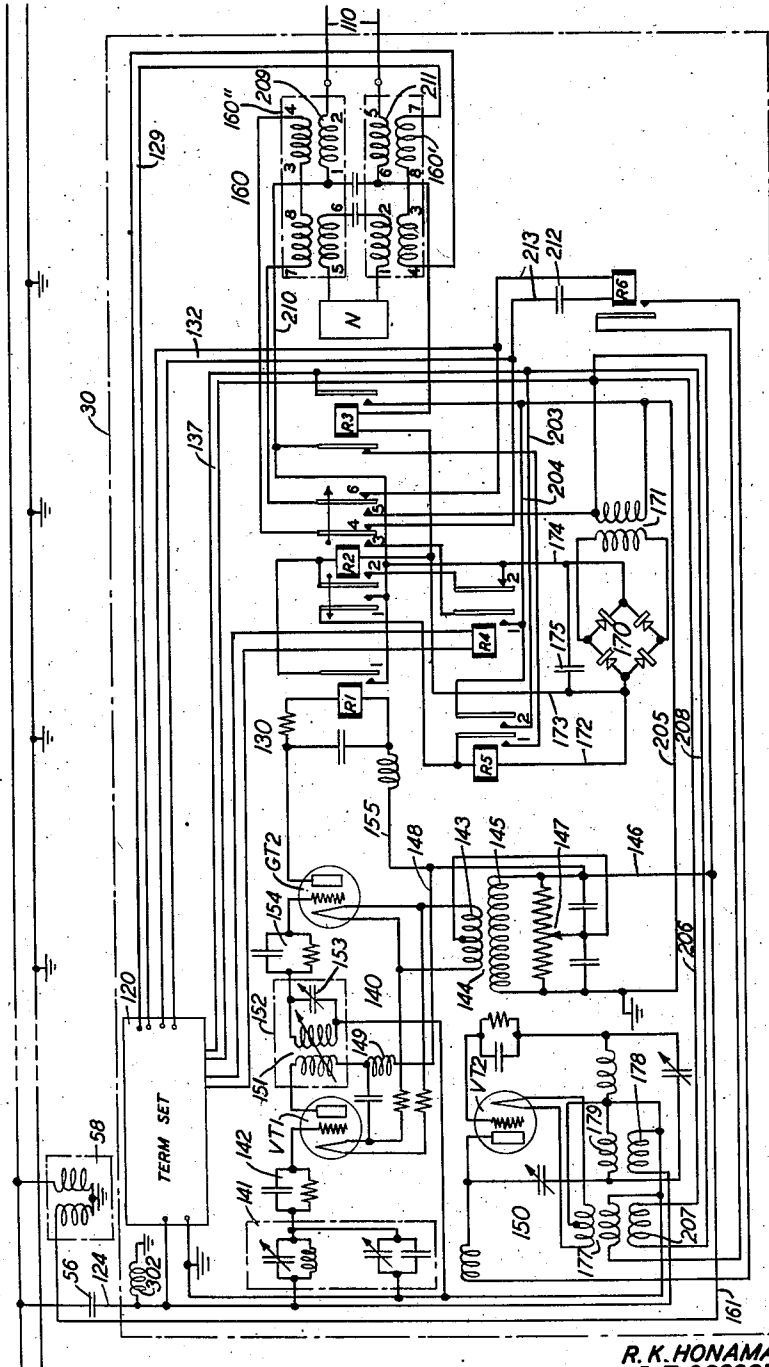
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3 Sheets-Sheet 2

FIG. 3



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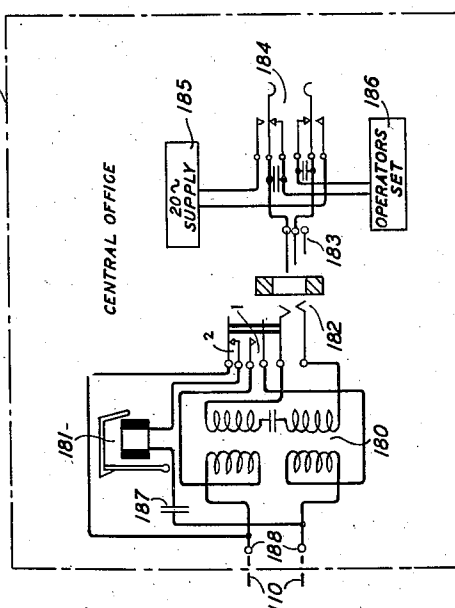
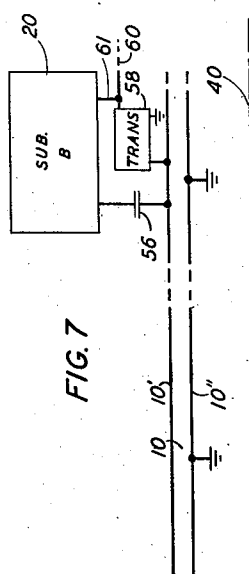
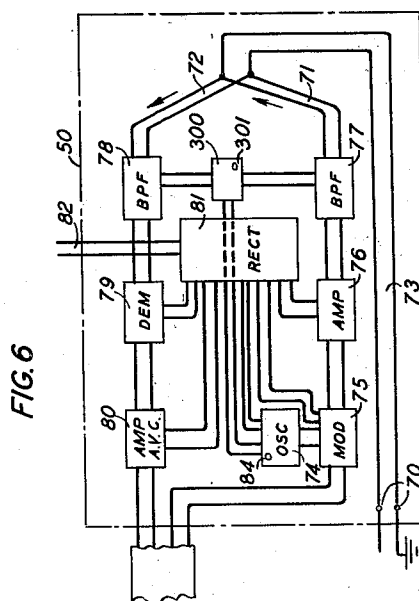
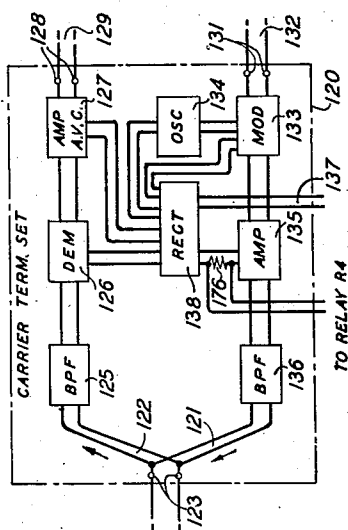
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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,294,905

POWER LINE TELEPHONE SYSTEM

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11 Claims. (Cl. 179—2.5)

This invention relates to electric wave transmission systems, and, more particularly, to a power line carrier frequency telephone system.

Carrier frequency telephony on transmission lines primarily intended for the transmission and distribution of low frequency, high voltage electric power has, of course, been known for some time, but has never been very extensively applied. The somewhat extensive electrification of rural areas that has taken place in the recent past and that appears to be projected for the future, and the possibility provided by the rural power lines of enabling telephone service thereover to the scattered inhabitants of the sparsely settled regions through which the power lines extend, have resulted in increasing interest in the possibility of telephony on such power lines by the use of high frequency carrier waves.

An object of this invention is to provide an improved system and means for signaling between a telephone station coupled to a power line and a central office or exchange for the telephone stations on the power lines.

Another object of the invention is to improve and to simplify the power supply to the power consuming relay, signaling and communication devices at the stations coupled to the power lines.

In accordance with this invention, a plurality of telephone stations and a central office or exchange for the telephone stations are coupled to a power line on which low frequency, high voltage electric power is being transmitted and distributed. Each telephone station comprises means for receiving from and transmitting to the power line a modulated high frequency or carrier wave. Each station may be arranged to transmit on one carrier wave and to receive on a second carrier wave, with means of interchanging the transmitting and receiving frequencies. The central office enables the connection of a telephone station on the power line to another station on the power line, and, also, to a party on another telephone system. Equipment for receiving and transmitting on the high frequency waves for the power line system may be incorporated in the central office, or, preferably, may be included in a high frequency or carrier terminal station enclosed in a suitable housing and supported on one of the poles carrying the power line. This terminal station enables communication and signaling between the telephone stations and the central office, and signaling between telephone stations on the same power line. Each telephone station is adapted to be signaled from the central office on a high frequency or carrier wave

different from that for conversational purposes, the signal wave operating a signaling circuit at the telephone station that includes a gaseous discharge device whose output circuit includes relay means for connecting power supply to the high frequency equipment at the telephone station so that it will be energized when the called party answers, or so that the high frequency equipment will be energized for a preassigned period only if the called party does not answer. Each telephone station is adapted to signal the central office on another high frequency or carrier wave, and to operate a gaseous discharge device signal and relay switching circuit at the terminal station to transmit a low frequency signaling current to the central office to operate a visual indicator of an incoming call thereto. All of the power required for operation of the relays and signaling and communication devices is preferably derived from the power line, and utilized either as the low frequency alternating current at transformed voltage or, after suitable rectification, as direct current.

A more complete understanding of the invention will be derived from the particular description that follows read with reference to the accompanying drawings illustrative of an embodiment of the invention wherein:

Fig. 1 is a schematic to show the general arrangement of a power line carrier frequency telephone system in accordance with the invention;

Fig. 2 shows a preferred circuit arrangement at a telephone station coupled to the power line of the system of Fig. 1;

Fig. 3 shows a preferred circuit arrangement for a carrier frequency terminal set or equipment coupled to the power line of the system of Fig. 1, whereby telephone stations coupled to the power line may connect with a central office or exchange for connections with parties in another or a general telephone system;

Fig. 4 shows a preferred circuit arrangement for the central office or exchange termination of the carrier frequency terminal equipment of Fig. 3;

Fig. 5 illustrates the nature of the carrier frequency circuit in the circuit arrangement of Fig. 3;

Fig. 6 illustrates the nature of the carrier frequency circuit at the telephone station shown in Fig. 1;

Fig. 7 shows a portion of the power line telephone system, with a subscriber station shown in schematic; and

Fig. 8 shows how the three sheets of these

drawings should be arranged for greater ease in understanding this disclosure.

Description of the power line carrier frequency telephone system

Fig. 1 shows in schematic a power line carrier frequency telephone system. The power line 10 is intended or designed for the transmission of electric power, for example, at high voltage and low frequency, and is adapted to have distribution transformers coupled to it for supplying power consumers along the line with electric power of low voltage, or lower voltage than that of the power line. Such a line might comprise a high voltage conductor 10' and a second conductor 10'', the latter being connected to ground at a multiplicity of points along its length and preferably at each point to which a distribution transformer may be coupled. Such a line may be of the pole supported type and be adapted to transmit alternating current of a commercial frequency, for example, 25 cycles per second or 60 cycles per second and of a potential of, for example, 7600 volts. Coupled to the power line at a plurality of geographically separated points are telephone subscriber stations 20, preferably at a location at which a distribution transformer is to be found. Each telephone station is adapted to be connected with the other stations and to communicate over the power line on an electric wave of frequency greater and preferably much higher than the frequency of the electric power being transmitted. One or more such carrier waves each of the order of several hundred kilocycles per second may be employed. Each telephone station, therefore, is provided with means to modulate high frequency electric or carrier waves in accordance with a telephone signal originating at the stations and to transmit such signals to the power line; and with means to demodulate a modulated high frequency electric or carrier wave incoming to the station, and to give a visual or aural indication of the modulation component. The modulated wave incoming to the station originates in one of the other telephone stations, or in a relay station or terminal set 30 coupled to the power line and adapted to connect the telephone stations on the power line with a central office or exchange 40 whereby the subscribers on the power line telephone system may be connected with subscribers of another or a general telephone system. Each telephone station may be coupled to the power line through a distribution transformer, for example, as described in L. K. Swart Patent No. 2,272,731, issued February 10, 1942; or through a suitably proportioned coupling condenser and high frequency transformer or retard coil. All power required by the telephone stations, and by the relay station or terminal set and associated equipment, is preferably derived from the power line.

Each telephone station 20 comprises, as shown in Fig. 2, a high frequency or carrier wave subscriber's set or equipment 50 including a hand telephone set 51 comprising a telephone receiver 52 and a telephone transmitter 53; a switching spring assembly 54; and a telephone station signaling circuit 55. The circuit of the telephone station is coupled to the high voltage conductor 10' of the power line through a connection 45 and a suitably proportioned capacitor 56 of low impedance to the high frequency electric or carrier waves employed for telephonic purposes but of high impedance to the low frequency of the

electric power being transmitted over the power line. The capacitor 56 is connected to retard coil 302, which is connected to ground. The coil has a high impedance to the carrier waves and a low impedance to the low frequency of the electric power. The primary winding 57 of the distribution transformer 58 is connected at one end to the conductor 10', and at its other end to ground. One end of the secondary winding 59 may be connected to ground also, the other end being connected by conductor 60 to power consuming electric devices such as lighting fixtures, motors, etc., as well as being connected to the telephone station by conductor 61. The potential developed across the winding 59 is preferably of some standard order, for example, 110 volts or 220 volts.

For purposes of this disclosure, it is assumed that, as has already been proposed in the art, each telephone station transmits on one high frequency electric or carrier wave F1 and receives on a second high frequency or electric or carrier wave F2 and includes means for interchanging the high frequency or carrier waves so that transmitting can be accomplished on wave F2 and receiving on wave F1. The carrier set 50 is shown in greater detail in Fig. 6. The terminals 70 of the set are common to a transmitting circuit or path 71, and a receiving circuit or path 72, being connected therewith through conductors 73. The transmitting circuit comprises the transmitter 53; an oscillator or other source 74 of the high frequency electric wave F1 or F2; a modulator 75 in which the high frequency wave is modulated in accordance with the voice frequency currents originating at the transmitter 53 and corresponding to sound waves impinging thereon; an amplifier 76 for amplifying the modulated high frequency wave to a preassigned degree; and a band-pass filter 77 adapted to transmit either or both side-bands of the modulated high frequency wave. The receiving circuit comprises the band-pass filter 78 adapted to transmit each or both of the side-bands of the incoming modulated high frequency wave; a demodulator 79 for translating the modulation component of the received modulated wave into voice frequency currents; an amplifier 80 with A. V. C. for amplifying the demodulator output to a preassigned degree; and the receiver 52 for translating the voice frequency current into sound waves corresponding to those produced at the calling station. The set also includes a suitable switching means, indicated by numeral 300, which changes the frequency of the oscillator 74 from F1 to F2 and interchanges the filters 77 and 78 when, for example, the button 301 is pressed. The amplifier, modulator, demodulator and oscillator may be of any known type, for example, those employing electron discharge devices or vacuum tubes, the operating potentials and currents therefor being supplied through a suitable rectifier 81, the input to which is derived from the transformer 58 through conductors 82, as will be described in greater detail hereinafter. Normally, that is, when the handset 51 is on its support 83, the telephone station carrier subscriber set 50 is not energized and does not consume any power. The oscillator would be one adapted to generate normally the high frequency F1, but be provided with a manually operated button 84, or other device, operation of which by the subscriber changes the constants of the oscillator's oscillatory circuit, so that the electric wave generated by the oscillator is of a different high frequency F3 so long as the button remains

operated, for a purpose explained more fully hereinafter.

The station signaling circuit 55 comprises a pair of relays R10, R20; an audible signaling means or ringer 90; a gaseous discharge device GT1; a tuned high frequency circuit or filter 92; an antiresonant network 93; and a time-delay element or relay cut-out T.

The device GT1 comprises an envelope containing a filament or cathode, an anode and a control grid in a gaseous atmosphere, for example, of a rare gas, such as argon. This tube is of the type in which, for any given anode potential, there is a critical grid potential. If the grid is held more negative than this value and the gas is not ionized, the anode current will be zero; if the grid is made less negative, the anode current assumes a value determined by the anode potential and the impedance of the anode circuit. Once ionization or discharge has started, the grid loses control over the anode current. Potentials for anode and the grid and heating current for the filament are continuously supplied from the secondary winding 59 of the transformer 58, the primary winding 95 of transformer 96 being connected at one end to ground and at its other end, through conductors 61, 97, to the ungrounded terminal of winding 59. The transformer 95 comprises a pair of secondary windings 98, 99, the former providing heating current for the filament, and the latter, grid biasing potential. A potentiometer 100 permits adjustment of the grid potential to take care of variations in tubes. The grid potential is preferably 180 degrees out of phase with the line voltage on the anode.

The filter 92 comprises an inductance 101 and a variable condenser 102 connected in parallel in its series arm, and an inductance 103 in its shunt arm. This filter is tuned to a high frequency electric wave F4 other than those for signaling to the central office or exchange, and for conversational purposes. The filter is connected to the power line conductor 10' through conductor 104 and the normally engaged springs 3, 4 of the assembly 54. In addition to discriminating against unwanted frequencies, the filter increases the voltage of the signal incoming to it by a preassigned amount, and applies it to the grid of tube GT1 through the grid leak and condenser network 105.

The characteristic of the tube GT1 should be such that there is nearly a linear relation between the voltages on the grid and on the anode that just causes ionization and the establishment of anode current flow. Thus, with a grid potential just in excess of that required to produce ionization, the tube will be equally sensitive for substantially the entire positive half of a 60 C. P. S. electric wave. The high frequency output of the filter 92 is subtracted from the initial or normal grid bias, and is of such a value as to reduce the grid bias to a value at which the tube ionizes. During each positive half cycle of the power supply to the anode, anode current will flow, that is, so long as the high frequency wave input to filter 92 continues, there will be a pulsating current flow in the filament-anode circuit of the tube.

The network 93 is connected between the grid and the anode of the tube GT1 to reduce the effect of the grid-to-anode capacity and of the filament-to-anode capacity.

The relay R10 is connected in series with the anode of tube GT1 and an inductor 106. The

ringer 90 is connected in parallel with relay R10. This relay and the ringer are adapted to be energized by the anode current when the tube ionizes or breaks down. Whenever the high frequency wave F4 is present in the input to the tube, the relay and ringer are energized by the pulsating current flow in the filament-anode circuit. The audible signal produced by the ringer notifies the subscriber at the telephone station of the incoming call thereto. An armature-and-contact set 107 is associated with the relay R10. The armature is permanently connected to the conductor 61, and its associated contact is permanently connected to one conductor of the power supply conductors 82 for the station carrier set, to spring 6 of assembly 54, and to the contact of the armature-and-contact set 108 associated with relay R20.

The winding of relay R20 has one end connected to spring 7 of assembly 54, and its other end connected through a current-limiting resistor 109 to ground, to one of the station carrier set power supply conductors 82, and to the spring 2 of assembly 54. Connected in shunt of the winding of relay R20 is a thermally-sensitive resistance element T, of the type that decreases in resistance with increase in temperature resulting from current flow therethrough. The element T is preferably proportioned so as to be initially of high impedance, and of substantially no effect on current flow through relay R20; and to become of sufficiently low impedance in a pre-assigned time, for example, two or three minutes, that the relay is substantially short-circuited. The armature of the armature-and-contact set 108 is permanently connected to the power supply conductor 61, and the contact is connected to spring 6 of assembly 54.

The switching spring assembly 54 comprises the springs 1, 2—7. When the handset 51 is on the support 83, springs 4 and 7 are in contact with springs 3 and 6, respectively, and springs 1, 2 and 5 are out of contact with support 83, spring 3 and spring 6, respectively. When the handset is removed from the support 83 the latter, together with springs 3 and 6, moves upwardly under the influence of a suitable spring element (not shown) whereby the contacts between springs 3 and 4 and springs 6 and 7 are broken, and support 83, spring 3 and spring 6 make contact with springs 1, 2 and 5, respectively.

The relay station or carrier terminal set 30 may be located at the central office or exchange 40, or, preferably, may be an isolated unit supported on one of the power line poles, suitably enclosed against the elements, and connected to the central office 40 through a telephone pair 110.

The relay station comprises a high frequency electric or carrier wave transmitting and receiving set or equipment 120; a signaling switching circuit 130 comprising a two-stage discharge device circuit 140, and a plurality of relays R1, R2 . . . R6; an oscillator 150 for generating a high frequency electric wave F4; and a hybrid coil 160 and balancing network N for coupling together the central office and the circuits at the relay station.

The carrier wave set 120, as shown in Fig. 5, comprises a transmitting branch or path 121, and a receiving branch or path 122 having common terminals 123, one of which is connected to ground and the other to the conductor 10' through the coupling condenser 56 and conductor 124. The receiving path comprises a band-pass filter 125 for transmitting one or both side-bands

of the modulated high frequency electric wave F1; a demodulator 126 for translating the modulation component of the modulated wave into voice frequency currents; and an amplifier 127, preferably embodying automatic volume control, for amplifying the voice frequency currents, the amplifier output being supplied through the terminals 128 to the conductors 129, the latter being connected at their other ends to terminals 4, 7 on the section 160' of the hybrid coil 160. The transmitting path comprises a pair of terminals 131 to which are connected conductors 132. At their other ends, the conductors 132 are connected through the contacts 4, 6 of relay R2 to the terminals 4, 7 of the section 160'' of hybrid coil 160. In the transmitting branch are a modulator 133, in which the voice frequency currents incoming to terminals 131 are modulated on the high frequency electric wave F2 originating in an oscillator 134; an amplifier 135 for amplifying the modulated wave F2; and the band-pass filter 136 for transmitting the amplified modulated wave to the terminals 123 and through them to the power line. As with the telephone station set 50, the amplifiers, modulator, demodulator and oscillator of the set 120 may be of the type employing electron discharge devices, the operating potentials and currents therefor being supplied over conductors 137 from the power line through a distribution transformer 58 and a suitable rectifier 138, as explained more fully hereinafter.

The discharge device circuit 140 comprises an input network or filter 141 tuned to the high frequency electric wave F3, and discriminating against the other high frequency waves employed in the system. Its series arm is connected between the high frequency conductor 124 and the grid leak and condenser network 142, and its shunt arm is connected between ground and a point intermediate the series arm and the network 142. The electron discharge device or vacuum tube VT1 comprises a filament, anode and control grid. Its filament is continuously energized from the secondary winding 143 of transformer 144. The primary winding 145 of the latter has one terminal connected to ground and its other connected through conductor 146 to conductor 161. The potentiometer 147 permits adjustment of the bias on the control grid. Anode potential is obtained from the high potential end of the primary winding of transformer 144 through connection 148, choke coil 149 and one winding of the interstage transformer 151. The control grid is biased 180 degrees out of phase with the voltage applied to the anode. The tube VT1 is coupled to a gaseous discharge device GT2, similar to the tube GT1, through a tuned circuit or network 152 comprising the variable-coupling transformer 151 and the variable capacitor 153. The network 152 enables further selectivity with respect to the electric wave F3. A grid leak and condenser network 154 is connected between the network 152 and the grid of tube GT2. The filament of the latter is continuously energized from the secondary winding of transformer 144, the biasing potential for its grid is determined by the adjustment of the potentiometer 147, and its anode potential is derived through connection 155 from the high potential end of the winding 145.

Relay R1 is connected in the filament-anode circuit of tube GT2 whose mode of operation is the same as that of tube GT1. The rectifier 170, for example, a bridge-type full-wave rectifier of dry rectifier elements, is continuously supplied with alternating current from the power line

through the distribution transformer 58 and the transformer 171. The rectified output of rectifier 170 is adapted to be supplied to relays R2, R3, R5, as energizing current, through the connections 172, 173, 174. The condenser 175 is an alternating current by-pass. Relay R4 is connected across a resistance 176 in the plate supply lead to the amplifier 135 of the terminal carrier set 120. Relay R6 is connected to the terminals 4, 7 of hybrid coil section 160'' through the contacts 4, 6 of relay R2, and is adapted to be operated by 20 C. P. S. alternating current originating at the central office. The sequence of operation of the relays R1, R2 . . . R6 will be described in detail in connection with a later description of the operation of the system disclosed.

The oscillator 150 is, for example, of the Hartley type, and is adapted to generate a high frequency electric wave of frequency F4. The electron discharge device VT2 derives its anode potential from the power line through the distribution transformer 58 and transformer 177, the alternating current being supplied to the anode of tube VT2 only when relay R6 is energized and, therefore, its associated pair of contacts closed. The high frequency wave generated by the oscillator is applied to the power line through the coil 178 coupled to the coil 179 in the filament-anode circuit of tube VT2.

The central office or exchange 40 may be of any well-known type. Only so much of the circuit and equipment thereat as is requisite for an understanding of the invention has been shown in Fig. 4. A repeating coil 180, an operator's signal or drop 181, a switchboard jack 182, operator's plug 183, and ringing key 184, are shown. A source 185 of 20 C. P. S. ringing current, and an operator's set 186 are also indicated. The carrier terminal station or relay station 30 is connected with the central office over the telephone pair 110. The energizing winding of the operator's signal 181 is connected in series with a blocking condenser 187 across the line terminals 188 at the central office, the drop being adapted to be actuated by an alternating current of 60 C. P. S. originating at the relay station. The circuit for the line windings of the repeating coil is normally interrupted by the open contact 1 associated with the jack 182, a normally closed contact 2 associated with the jack 182 being included in the circuit for the drop 181.

Call from power line telephone station to the central office

The completion of a connection between a telephone station on the power line and the central office will now be described, the connection originating at the subscriber's station A. Let it be assumed that the party at station A wishes to be connected with a telephone subscriber on another telephone system.

The party at station A removes the handset 51 from the support 83. Normally-engaged contact springs 3—4 and 6—7 of assembly 54 are disengaged, and contact is made between spring 1 and support 83 and between contact springs 2—3 and 5—6. Engagement of spring 1 and support 83 connects the carrier set 50 to the power line, and engagement of springs 5—6 completes a power supply circuit for the set 50 from the transformer 58 as follows: Ungrounded terminal of winding 59, conductors 61 and 201, springs 5—6, conductors 82 to and from the rectifier 81 (Fig. 6), conductor 202 to ground return. Closure of springs 2—3 connects the input terminal of the

network 92 to ground. The rectifier 81 supplies the oscillator, modulator, demodulator and amplifier with energizing current and potential. After a short wait for the thermionic devices in the carrier set to heat up, and after listening to ascertain that the power line is not in use by another telephone subscriber on the line, the calling party operates the button 84 to cause the oscillator to generate the high frequency carrier wave F3. The high frequency wave F3 is impressed on the power line through the terminals 70 of the carrier set, and is transmitted along the power line to the relay station 30.

The high frequency wave F3 is applied to the filter 141 and transmitted to the amplifying device VT1. After amplification, the signal wave is transmitted by the interstage network 152 to the grid-cathode circuit of the gaseous discharge device GT2. So long as the signal wave input to the device GT2 continues, pulsating direct current flows in its cathode-anode circuit, and the relay R1 is energized and its associated normally-open contact set is closed. Operation of relay R1 closes the following circuit for the energization of relay R2: One output terminal of rectifier 170, conductor 174, contact set of relay R1, winding of relay R2, conductor 173, back to the other output terminal of the rectifier 170. Energization of relay R2 causes its associated normally-open contact sets 1, 2, 3, 5 to close, and normally-closed contact sets 4, 6 to open. Closure of contact set 2 of relay R2 locks the latter in its operated condition over the following circuit: One output terminal of rectifier 170, conductor 174, normally-closed contact set 2 of relay R4, contact set 2 of relay R2, winding of relay R2, conductor 173 back to the other output terminal of rectifier 170. Normally the serially-connected outer windings of section 160'' of the hybrid coil are connected through contact sets 4, 6 of relay R2 to the voice frequency input conductors 132 of the carrier set 120. Closure of contact sets 3, 5 of relay R2 disconnects the hybrid coil winding, and, therefore, the telephone line 110 from the conductors 132. Closure of contact set 1 of relay R2 completes the following energizing circuit for relay R5: One output terminal of rectifier 170, conductor 174, contact set 1 of relay R2, winding of relay R5, conductor 172 to the other output terminal of rectifier 170. Normally-open contact sets 1, 2 associated with relay R5 close when the latter is energized. Closure of contact set 1 of relay R5 locks the relay R5 in operated condition over the following circuit: One output terminal of rectifier 170, conductor 174, normally-closed front contact set of relay R3, contact set 1 and winding of relay R5, conductor 172 to the other output terminal of rectifier 170. Closure of contact set 2 of relay R5 completes the alternating current power supply circuit to the carrier set 120 and to the oscillator 150. The power supply circuit for the carrier set may be traced as follows: From the non-grounded terminal of the secondary winding of transformer 58, conductor 161, conductors 137 to and from the rectifier 138 in the carrier set 120, conductor 203, contact set 2 of relay R5, conductors 204 and 205 to ground return. The power supply circuit for the oscillator may be traced as follows: From the non-grounded terminal of the secondary winding of transformer 58, conductors 161 and 206, primary winding 207 of transformer 177, conductors 208 and 203, contact set 2 of relay

R5, conductors 204 and 205 to ground return. The thermionic devices in the amplifiers, modulator, demodulator and oscillator of the set 120 are energized from the output of the rectifier 138; and the tube VT2 from the filament and anode windings of transformer 177. As the tubes of the amplifier 135 heat up, the potential drop across the resistance 176 will reach a preassigned value and cause relay R4 to operate, to close its associated normally-open contact set 1 and to open its normally-closed contact set 2. Closure of contact set 1 of relay R4 closes the following circuit: Non-grounded terminal of the secondary winding of transformer 58, conductor 161, contact set 5 of relay R2, serially-connected upper windings of hybrid coil section 160'', contact set 3 of relay R2, contact set 1 of relay R4, conductors 204 and 205 to ground return. The alternating current induced in the hybrid coil line winding 209 operates the magnetic drop 181 at the central office, to provide the operator with a visual indication. The opening of contact set 2 of relay R4 breaks the holding circuit for relay R2 and the latter releases. The release of relay R2 restores its associated contact sets 1 . . . 6 to the condition shown on the drawings, but relay R2 is sufficiently slow in releasing to permit the alternating current signal to the central office to operate the drop 181. Relay R5 does not deenergize as a result of the restoration to normal of contact set 1 of relay R2, but remains operated through the holding circuit including its own contact set 1.

The operator responds to the signal by inserting the plug 183 into the jack 182. Normally-closed contact set 2 of the jack is opened to break the circuit for the signal 181, and normally-open contact set 1 of the jack is closed to complete a direct current circuit through the normally-open line winding of repeating coil 180. This circuit is as follows: One output terminal of rectifier 170, conductors 174 and 210, hybrid coil winding 209, one conductor of line 110, the repeating coil line winding including the jack contact set 1, the other conductor of line 110, hybrid coil winding 211, winding of relay R3, conductor 173 to the other output terminal of rectifier 170. Relay R3 operates. The opening of its front contact set breaks the holding circuit for relay R5, and the latter releases; but closure of the back contact set of relay R3 in parallel with the contact set 2 of relay R5 maintains the alternating current supply to the carrier set 120.

When the operator answers the signal from the subscriber, i. e., speaks to the subscriber, the audio frequency currents originating at the central office are transmitted over the telephone line 110 through the hybrid coil 160, contact sets 4, 6 of relay R2 and conductors 132 to the set 120. In the modulator 133 they are modulated onto the carrier wave F2 from the oscillator 134. The modulated carrier wave is amplified in amplifier 135 and transmitted through the filter 136 and power line terminals 123 to the power line. At the subscriber's station, the modulated carrier wave enters the carrier set 50 through terminals 70, is transmitted by filter 78 to the demodulator 79, and the demodulated output is amplified by the amplifier 80 and transmitted to the receiver 52. The subscriber at station A having restored the button or key 84, the output of the oscillator 84 will be at its normal frequency, that is, of carrier wave F1. When the calling party talks to the operator, the sound waves are translated by the transmitter 53 into voice frequency currents

which are impressed on the modulator 75, in which they are modulated onto the carrier wave. F1 supplied by the oscillator 74. The modulated carrier wave is amplified by amplifier 76 and transmitted through the filter 77 to the terminals 70, and are impressed on the power line. At the relay station, the modulated carrier wave enters the terminal set 120 through terminals 123, and is transmitted by filter 125 to the demodulator 126, the audio frequency output of which is amplified in amplifier 127 and transmitted through terminals 128 to the conductors 129. The conductors 129 are connected to the outer ends of the serially-connected lower windings of hybrid coil section 160'. The audio frequency currents will be induced in winding 211 and the winding connected to the balancing network N. The currents induced in winding 211 are transmitted over the line 110 and through the repeating coil, the jack and the plug to the operator's set. If it is assumed that the party at station A wishes to be connected to a party on another telephone system, the operator completes the connection through the conventional switchboard and central office cord facilities (not shown). When the call is finished, the subscriber at station A operates the button 84 to transmit the signal wave F3 to the power line and to the relay station. This wave is amplified by the tube VT1 and impressed on the tube GT2, the pulsating output of tube GT2 operating relay R1 and relay R2 as already described. Relay R2, however, does not lock up since its holding circuit is held open at contact set 2 of relay R4. During the period that relay R2 is operated, its contact sets 3, 5 are closed, and contact sets 4, 6 are opened. The serially-connected upper windings of hybrid coil section 160'', therefore, are connected during that period to the alternating current supply, and the alternating current is induced in hybrid coil winding 209 and transmitted to the central office over the line 110 to operate a supervisory relay or magnetic drop in the cord circuit thereat. When the operator disconnects the cord circuit, the direct current circuit holding relay R3 operated is broken at contact set 1 of the jack 182. Relay R3 releases, disconnecting the alternating current power supply from the carrier set 120, causing relay R4 to release, and restoring the relay station to its non-operated condition.

Call from central office to power line telephone station

Let it now be assumed that the operator at the central office wishes to signal a telephone station, for example station A, to complete a call from another subscriber on the power line or from a party in another telephone system.

The operator inserts plug 183 in jack 182 completing the direct current circuit for relay R3 through contact set 1 of the jack. Closure of the back contact set of relay R3 connects the alternating current power supply to the set 120 and the oscillator 150. After a short interval in which the filament of the tube VT2 may heat up, the operator operates key 184 to connect low frequency signaling current from source 185 to the repeating coil. Relay R6 is tuned by means of the series condenser 212 to operate on this signaling current, which reaches it over line 110, the hybrid coil, contact sets 4, 6 of relay R2, and conductors 213. Closure of the front contact set of relay R6 completes the anode potential circuit of the tube VT2. The oscillations of high frequency or carrier wave F4 developed in wind-

ing 179 are induced in winding 178, and impressed on the power line.

Each telephone station will be in the condition shown for station A (except, of course, the station on the power line at which the call originated, if such is the case), and the high frequency wave F4 will be impressed on the input network 92 of each station through connection 45, contact springs 3—4 of assembly 54 and conductor 104. The network 92 selectively transmits the signal wave F4 to the control grid of the gas tube GT1. The normal grid potential is reduced sufficiently to permit ionization during each half cycle that the anode potential is positive, whereby pulsating direct current flows in the cathode-anode circuit of the tube so long as the signal wave F4 is incoming to the station. Ringer 90 and relay R10 operate, the former to give an audible indication of the incoming call, and the latter to close its associated contact set 107. Closure of contact set 107 completes a power supply circuit for the carrier set 50 over the following path: Non-grounded terminal of winding 59 of transformer 58, conductor 61, contact set 107, conductors 82 to and from the rectifier 81 of the set 50, conductor 202 to ground return. The relay R20 operates over the following circuit: Non-grounded terminal of winding 59 of transformer 58, conductor 61, contact set 107, conductor 214, contact springs 6—7 of assembly 54, winding of relay R20, resistance 109, conductor 202 to ground return. Energization of relay R20 causes contact set 108 to close, to hold relay R20 in operated condition over the following circuit: Non-grounded terminal of transformer winding 59, conductor 61, contact set 108, contact springs 6—7 of assembly 54, winding of relay R20, resistance 109, conductor 202, to ground return. Closure of contact set 108 provides an alternative power supply circuit for the carrier set 50, namely: Non-grounded terminal of transformer winding 59, conductor 61, contact set 108, conductors 82 to and from rectifier 81, conductor 202 to ground return. Relay R20 remains operated until the handset 51 is removed from the support 83, thereby opening its energizing circuit at the contact springs 6—7 of assembly 54; or, if the handset 51 is not removed from its support, relay R20 remains operated until the temperature sensitive variable resistance T decreases in resistance sufficiently to substantially short-circuit the relay R20. Prior to either event, however, the output of the rectifier 81 energizes the thermionic devices in the set 50. The incoming signal equipment at each station will be operated when the signal wave F4 is impressed on the power line, but by use of a suitable code, the particular station desired by the operator will be informed thereof. When the called subscriber removes his handset from its support, the holding circuit for relay R20 is broken at contact springs 6—7 of assembly 54, the carrier set is connected to the power line by engagement of contact spring 1 and support 83 of assembly 54, power supply to the rectifier 81 of the set 50 is insured by engagement of contact springs 5—6 of assembly 54, and engagement of contact springs 2—3 of assembly 54 connects the ungrounded terminal of network 92 to ground. When the called party terminates his conversation with the operator or other party to whom he is connected by the operator, he operates the button 84 on oscillator 74 to transmit signal wave F3 for operation, as already described, of the supervisory relay in the cord circuit at the central office, and replaces the

handset 51 on its support to restore the station circuit to the condition shown in Fig. 2.

Connection between two telephone stations on the power line

The manner in which a connection would be established between two stations A and B coupled to the power line will be readily apparent. If it is assumed that the party at station A wishes to be connected with the party at station B, the former initiates the call by removing the handset from its support, and signaling on frequency F3 to the operator at the central office, in the manner already described. Informed that connection with station B is desired, the operator, in the manner described hereinabove, signals out onto the power line on carrier wave F4, using the preassigned signaling code for station B. The party at station A operates button 301 on his set 50 after informing the operator that he desires connection with station B on the same power line. When the latter answers, conversation between the parties at stations A and B takes place over the power line. Station A transmits on frequency F2 while station B receives on frequency F2, and station A receives on frequency F1 while station B transmits on the latter frequency. Operation of button 301 by the party at station A interchanges the normal transmitting and receiving frequencies for station A. The operator's plug remains in the jack 182 so that relay R3 remains energized and the operator is thus informed that the power line is in use. When the conversation has been concluded, the calling party, here the party at station A, signals to the operator on the carrier wave F3 before replacing the handset on its support. Withdrawal of the plug 183 from the jack 182 restores the relay station to its non-operated condition.

Although this invention has been disclosed with reference to a particular embodiment, it will be understood that it is not limited thereto but only by the prior art and the appended claims.

What is claimed is:

1. In a power line carrier frequency telephone system comprising a plurality of carrier frequency telephone stations connected to said power line, means at each station comprising a network selective to a signaling carrier wave, a gas-filled tube including a cathode, an anode, and a control electrode, means to apply audio frequency alternating current to said cathode and anode and to bias said control electrode to a potential maintaining said tube normally deionized, means connecting said network and said control electrode for applying said signaling carrier wave to said electrode to overcome the bias thereon whereby said tube ionizes during the half cycles of said alternating current in which said anode is at positive potential and generates an audio frequency pulsating current, and means connected to the cathode and anode of said tube to be actuated by said pulsating current.

2. In a power line carrier frequency telephone system, a power line for transmitting audio frequency alternating current electric power and a carrier frequency telephone station connected to said power line, said station comprising carrier wave equipment including circuits for transmitting to and receiving from the power line the carrier wave modulated in accordance with audio frequency currents corresponding to sound waves originating at the telephone station or at another station connected to the power line, means at the station comprising a network selective to

a signaling carrier wave, a gaseous discharge device including a cathode, an anode, and a control electrode, means to apply audio frequency alternating current to said cathode and anode and to bias said control electrode to a potential maintaining said device normally deionized, means connecting said network and said control electrode for applying said signaling carrier wave to said electrode to overcome the bias thereon whereby said device ionizes during the half cycles of said alternating current in which said anode is at positive potential and generates a pulsating audio frequency signal, and means connected to said anode and cathode to be actuated by said pulsating signal.

3. A power line carrier frequency telephone system comprising a power line for transmitting low frequency, high voltage alternating current electric power, a plurality of telephone stations coupled to said line and adapted to receive and to transmit modulated carrier waves over said power line, means at each station selective to a signaling carrier wave of frequency other than that used for modulated carrier wave transmission, a gaseous discharge device comprising a cathode, an anode and a control grid, energized with alternating current derived from said power line, said device normally being deionized because of excessive grid bias, means connected to said selective means to apply said signaling carrier wave to said grid to overcome the grid bias sufficiently to enable the anode to take control during the positive half cycles of the alternating current, so that the device develops a pulsating direct current in its cathode-anode circuit, and means in said cathode-anode circuit to be actuated by said pulsating direct current.

4. In a power line carrier frequency telephone system, a power line and a telephone station coupled to said power line, said station comprising a carrier wave equipment including circuits for transmitting to and receiving from the power line a carrier wave modulated in accordance with audio frequency currents corresponding to sound waves originating at the telephone station or at another station connected with the power line, means for connecting and disconnecting said circuits from the power line, said circuits being normally disconnected from said power line, a normally-open power supply connection between said power line and said carrier wave equipment, means responsive to a signaling carrier wave of frequency other than that of the audio frequency modulated carrier wave for completing said power supply connection, and means to restore said power supply connection to its normally-open condition after a preassigned time has elapsed if the carrier wave circuits of said carrier wave equipment are not connected to said power line by the party at the telephone station.

5. A power line carrier frequency telephone system comprising a power line, a plurality of telephone stations coupled to said line and adapted to receive and to transmit over said power line carrier waves modulated in accordance with audio frequency currents corresponding to sound waves, means at each station selective to a carrier wave of frequency different from that used for audio frequency modulation, a gaseous discharge device normally deionized, means to supply an audio frequency alternating current to said device, an input circuit for said device connected to said selective means whereby

carrier wave transmitted by said selective means is applied directly to said device to cause it to ionize on alternate half cycles of said audio frequency alternating current and to deliver an audio frequency pulsating output, an output circuit for said device, and means in the output circuit of said device to be actuated by said pulsating output.

6. A power line carrier frequency telephone system comprising a power line, a plurality of telephone stations coupled to said power line and each including a carrier set adapted to receive and to transmit modulated carrier waves, and an incoming call signal means at each station comprising a network tuned to a signaling carrier wave of frequency different than that for modulated carrier wave transmission, a gaseous discharge device normally deionized and adapted to be ionized by the signaling carrier wave passed by said network, an output circuit for said device, a plurality of normally open power supply circuits for said carrier set, a relay in the output circuit of said device to be operated when said device ionizes and to close one of said power supply circuits, a second relay to be operated when said first relay operates and to close a second of said power supply circuits, the operation of said relays providing successively different power supply circuits for the carrier set and the operation of said second relay providing the latter with an energizing circuit independent of said first relay whereby said second relay remains operated after said first relay ceases to be operated, said second relay including an energizing winding, and means in shunt with the winding of said second relay to deenergize it after a preassigned interval if the called subscriber does not respond.

7. A telephone system as claimed in the preceding claim in which said shunt means comprises a thermosensitive resistance element having a negative temperature coefficient of resistance.

8. In a power line carrier frequency telephone system, a power line for transmitting low frequency electric power, a plurality of telephone stations connected to said power line and adapted to receive from and to transmit to said power line a carrier wave modulated in accordance with audio frequency currents corresponding to sound waves, a central office for said telephone stations connected to said power line, and means for signaling a telephone station from said central office, said means comprising a thermionic oscillator to be operated directly by alternating current from said power line and adapted to generate a high frequency signal wave, said oscillator having a normally-open power supply connection between it and the power line, and a normally-open connection between its output circuit and the power line for impressing the signal wave on the power line, means suc-

cessively to close said power supply and signal wave connections whereby the oscillator generates the signal wave and the latter is impressed on the power line, and means at each station selectively responsive to said signal wave to indicate that said signal wave is incoming thereto.

9. In a power line carrier frequency telephone system, a power line for transmitting low frequency electric power, a plurality of telephone stations connected to said power line and adapted to receive from and transmit to said power line a carrier wave modulated in accordance with audio frequency currents corresponding to sound waves, a central office for said telephone stations connected to said power line, and means for signaling a telephone station from said central office comprising a thermionic oscillator to be operated directly on alternating current from said power line, for generating a high frequency signal wave, a normally-open power supply connection between said power line and said oscillator, means for closing said power supply connection to said oscillator, a normally-open connection between the output circuit of said oscillator and the power line, means for closing said connection between the oscillator output and said power line, means at said central office for successively operating said two last-mentioned means whereby said power supply connection to the oscillator and the oscillator output connection to the power line are closed, and means at each telephone station selectively responsive to said signal wave to give an indication at the station that said signal wave is incoming thereto.

10. In a power line carrier frequency telephone system, a power line for transmitting low frequency electric power, a plurality of carrier frequency telephone stations and a carrier terminal station for said telephone stations connected to said power line, and a central office for said telephone stations connected to said carrier terminal station, means at each telephone station for impressing a signal wave on said power line, means at said carrier terminal station responsive to said signal wave incoming thereto from said power line to transmit low frequency alternating current derived from said power line to said central office, and means at said central office operating on said alternating current to indicate to the operator at the central office that a call is incoming thereto.

11. The power line carrier frequency telephone system as claimed in claim 4 in which said restoring means includes a resistance element that undergoes a substantial change in impedance with change in its temperature in response to power supplied to it from said power line.

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