

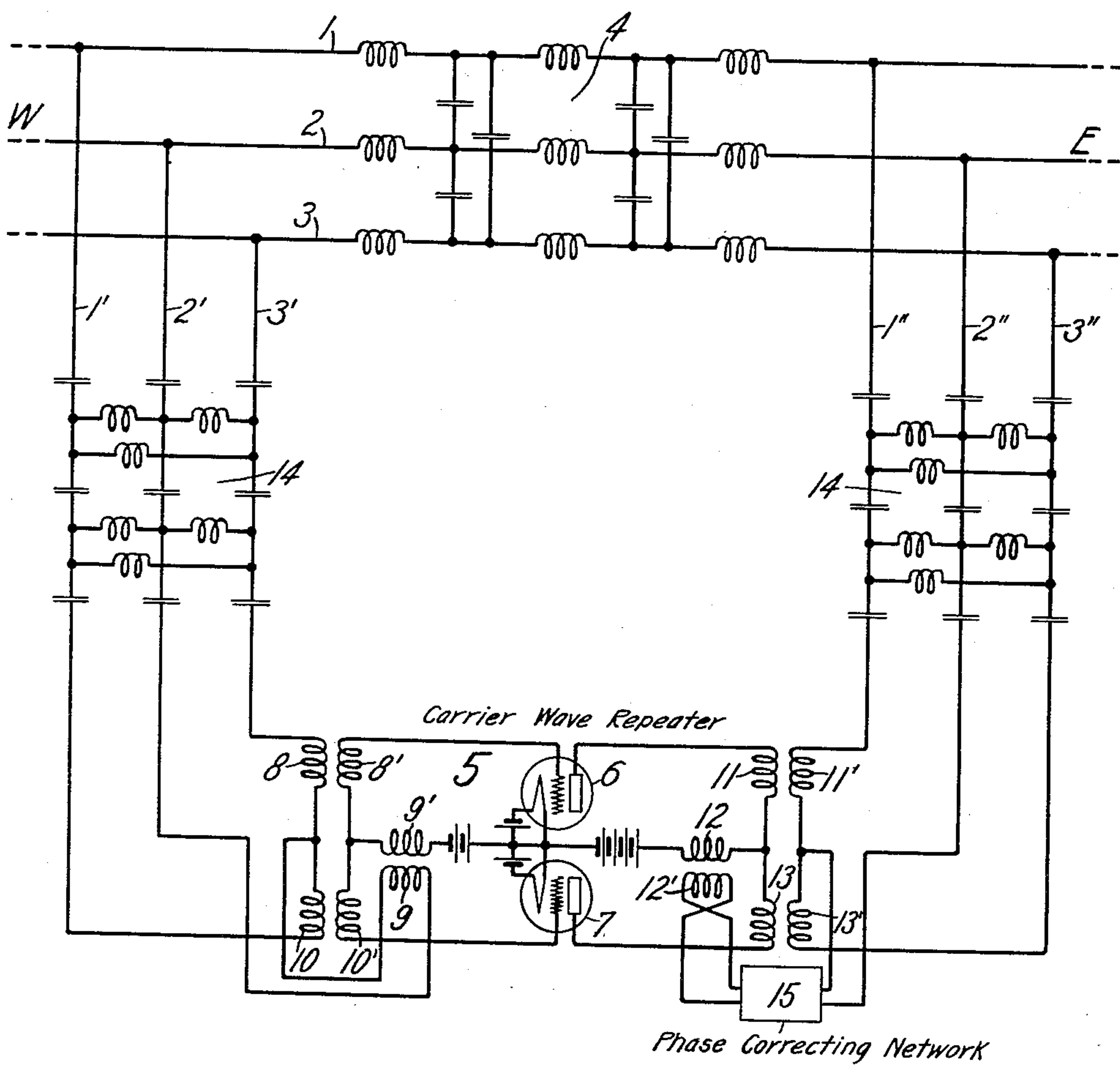
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CARRIER WAVE REPEATER

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CARRIER-WAVE REPEATER.

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This invention relates to repeaters for composite power current and carrier wave transmission systems.

An object of the invention is to repeat three-phase carrier waves comprised within a wide range of frequencies.

Another object of the invention is to reduce the number of repeating devices employed in three-phase transmission systems.

A feature of the invention is a repeater having two amplifying devices which are adapted to repeat three-phase signaling waves. In operation the two amplifying devices are used separately for repeating the waves in two phases and jointly for repeating the waves in the third phase. The invention thus makes it possible to span a given geographical distance at considerably smaller installation and maintenance costs than where separate amplifiers are employed for repeating the waves in each phase.

The invention will be described in detail in connection with the accompanying drawing which is a diagrammatic illustration of a circuit embodying the invention. While the description refers to carrier wave communication systems, it is obvious that the invention may also be employed in other systems, and in other parts of a system as well as at repeater points.

In the drawing, the line sections W and E comprising conductors 1, 2 and 3 of a three-phase power transmission system are connected together at a mid-line repeater by means of a three-phase low pass filter 4, the purpose of which is hereinafter described.

All three phases of the transmission system may be utilized for the transmission of power currents and for the simultaneous transmission of signal modulated carrier waves in both directions over the line. The preferred method of modulating the carrier waves and applying them in balanced relation to the conductors of the power line is disclosed and claimed in my copending application, Serial No. 70,529, filed November 21, 1925. The system described in that application provides means for generating modulated three-phase waves in which two-phase waves are first produced from a single wave, modulated by a common signal wave, and then converted into three-phase waves which are distributed in balanced relation to the three-phase conductors of the power line.

According to common carrier practice, the

signal modulated waves which are transmitted over the power line are grouped as to their frequencies, the higher frequencies, as a group, being transmitted from line section W to line section E, and the lower frequencies, as a group, being transmitted from line section E to line section W. The signal modulated waves in all three phases incoming at the repeater from line section W are amplified in the one-way repeater 5, and the amplified waves are delivered to line section E. A two-way repeater may be provided by duplicating the repeating apparatus to provide a path for operation in the opposite direction.

The one-way repeater 5 comprises a pair of three-element space discharge tubes 6 and 7 connected in push-pull relation. The usual sources of electrical energy are provided to properly polarize the grid electrodes, to heat the cathodes, and to furnish anode-cathode current.

Branch conductors 1', 2' and 3', leading from the conductors of line section W, are Y-connected to the input circuits of the push-pull amplifier by means of a three-phase transformer having three similar pairs of windings 8-8', 9-9' and 10-10', the secondary windings being designated by reference numerals corresponding to the associated primary windings, but with primes affixed thereto. The secondary windings 8' and 10' are connected in the individual input circuits of tubes 6 and 7, respectively, while the secondary winding 9' is connected in the common branch of the input circuits. The branch conductors 1'', 2'' and 3'', which are associated with the conductors of line section E, are also Y-connected to the output circuits of the push-pull amplifier by means of a three-phase transformer having the three phases magnetically coupled in the customary manner having three similar pairs of windings 11-11', 12-12' and 13-13', the primes in each case identifying the secondary windings. The primary windings 11 and 13 of this transformer are connected in the individual output circuits of tubes 6 and 7, respectively, while the primary winding 12 is connected in the common branch of the output circuits.

Similar three-phase broad band filters 14 are connected to the branch conductors between the repeater and the conductors of the power line. These filters serve not only to

separate the directional groups of carrier frequencies which are transmitted over the power line, but also to prevent the high voltage power currents from entering the carrier repeating apparatus. The low pass filter 4 inserted in the power line between the line sections W and E serves to divert substantially all the high frequency signal modulated waves into the repeater without interfering with the normal transmission of power currents. This filter also serves to prevent the high frequency signal modulated waves in the output of the repeater from being transmitted back to the input, and thus prevents singing in the repeater. As described in my copending application, mentioned above, the design of the three-phase filters may be accomplished in accordance with the rules for the design of simple two-wire filters such as disclosed in Patent No. 1,227,113, issued to G. A. Campbell, May 22, 1917. It follows, therefore, that a three-phase filter can be constructed to correspond to each type of simple filter, and consequently that many other types than those shown may be used in the three-phase system.

The three-phase signal modulated waves which are transmitted to the input circuits of the repeater from branch conductors 1', 2' and 3' will produce equal voltages 120° apart in the secondary windings 8', 9' and 10' of the three-phase input transformer. If these three voltages are represented by e_1 , e_2 and e_3 , respectively, then

$$\begin{aligned} e_1 &= e \sin \left(\omega t - \frac{2\pi}{3} \right) \\ e_2 &= e \sin \omega t \\ e_3 &= e \sin \left(\omega t + \frac{2\pi}{3} \right) \end{aligned}$$

The repeater amplifier has a straight line amplification characteristic which may be represented by the equation, $i_o = a_1 e$, in which a_1 is the amplifying factor of the circuit. If i' represents the output current through one tube and i'' represents the current through the other tube, then,

$$\begin{aligned} i'_{e1} &= a_1 e \sin \left(\omega t - \frac{2\pi}{3} \right) \\ i'_{e2} &= a_1 e \sin \omega t \\ i' &= i'_{e1} + i'_{e2} = a_1 e \left[\sin \omega t + \sin \left(\omega t - \frac{2\pi}{3} \right) \right] \\ &= a_1 e \sin \left(\omega t - \frac{\pi}{3} \right) \quad (1) \end{aligned}$$

and further

$$\begin{aligned} i''_{e3} &= a_1 e \sin \left(\omega t + \frac{2\pi}{3} \right) \\ i''_{e2} &= a_1 e \sin \omega t \\ i'' &= i''_{e3} + i''_{e2} = a_1 e \left[\sin \left(\omega t + \frac{2\pi}{3} \right) + \sin \omega t \right] \\ &= a_1 e \sin \left(\omega t + \frac{\pi}{3} \right) \quad (2) \end{aligned}$$

The current, i_o , through the common branch

of the output circuits is the vector sum of the currents in the individual output circuits of the two tubes. That is,

$$\begin{aligned} i_o &= i' + i'' = a_1 e \left[\sin \left(\omega t - \frac{\pi}{3} \right) + \sin \left(\omega t + \frac{\pi}{3} \right) \right] \\ &= a_1 e \sin \omega t \quad (3) \end{aligned}$$

Assuming the windings 11—11', 12—12' and 13—13' in the output circuits to be equal in impedance and winding ratio, and assuming K to represent the ratio of the secondary voltage to the primary current in each case, then from equations (1), (2) and (3) the voltages in the output circuits of the repeater amplifier may be represented as,

$$\begin{aligned} V_{11'} &= K a_1 e \sin \left(\omega t - \frac{\pi}{3} \right) \\ V_{12'} &= K a_1 e \sin \omega t \\ V_{13'} &= K a_1 e \sin \left(\omega t + \frac{\pi}{3} \right) \end{aligned}$$

It will be noted that $V_{11'}$, $V_{12'}$ and $V_{13'}$ are equal in magnitude and separated in phase by 60 degrees. The secondary winding 12' which is coupled to the common branch of the output circuits is reversed in order that the three output voltages which are impressed upon the three-phase power line will have a mutual phase relation of 120 degrees. A correcting network 15 may be employed in circuit with the secondary winding 12' of the output transformer to correct for any slight irregularities in the vector relation between the three phases.

The operation of the system may also be illustrated in another manner without the aid of mathematical analysis. The two E. M. F.'s in the secondary windings 8' and 10' of the input transformer combine to produce a single E. M. F. which is in quadrature with the E. M. F. in the winding 9', and which is greater than that E. M. F. in the ratio $\sqrt{3} : 1$.

The larger E. M. F., namely that due to windings 8' and 10', is applied to the two grids of amplifiers 6 and 7 in series, and the smaller E. M. F. is applied to the two grids in parallel.

Each E. M. F. may be considered to produce a corresponding current in the output circuit and corresponding voltages at the output transformer terminals. The E. M. F. applied to the grids in series produces a current which passes through output transformer windings 11 and 13 in series, and which, by virtue of the coupling of the phases produces zero effect in the winding 12. The E. M. F. applied in parallel produces output currents which traverse windings 11 and 13 in opposite directions and combine additively in winding 12. By virtue of the coupling of windings 11 and 13 this current is not impeded by these windings.

The net result of the operation is to es-

establish a pair of unequal voltages across windings 12 and the combination of 11 and 13 respectively, these voltages being in quadrature and, since both are amplified equally, in the same ratio as the impressed voltages, namely $\sqrt{3} : 1$. By the secondary windings of the output transformer these voltages are impressed upon the three-phase line and combine therein to produce a symmetrical three-phase current.

From the above description it will be noted that the voltages in the transformer windings 8 and 10 are amplified separately by the tubes 6 and 7, respectively, while the voltage in the transformer winding 9 is amplified jointly by both tubes. This construction effects a material saving in the initial installation cost as well as in maintenance costs, particularly where the successful operation of the carrier apparatus depends on the use of repeaters at comparatively frequent intervals on the power line.

What is claimed is:

1. The combination with a system for transmitting three-phase signaling waves, of a repeater comprising a pair of translating devices and connections between said system and said repeater for enabling said translating devices to repeat waves in all three phases.

2. The combination with a system for transmitting three-phase signaling waves, of a repeater comprising a pair of translating devices and connections between said system and said repeater for enabling said translating devices to repeat individually the waves in two phases and to repeat jointly the waves in the third phase.

3. The combination with a system for transmitting three-phase signaling waves, of a repeater comprising a pair of translating devices connected in push-pull relation, means for impressing the waves in two phases individually upon said devices, and means for impressing the waves in the third phase jointly upon said devices.

4. The combination with a system for transmitting three-phase signaling waves, of a repeater comprising a pair of amplifying devices having balanced input circuits, and a three-phase transformer for impressing the waves in two phases individually upon said input circuits and for impressing the waves in the third phase upon both of said input circuits.

5. The combination with a system for transmitting three-phase signaling waves, of a repeater comprising a pair of amplifying devices having balanced input circuits including a common branch, means for impressing the waves in two phases individually upon said input circuits, and means for impressing the waves in the third phase upon the common branch of said input circuits.

6. The combination with a system for transmitting three-phase signaling waves, of a repeater comprising a pair of amplifying devices having balanced input circuits including a common branch, and a transformer having a plurality of similar windings adapted to impress the waves in two phases individually upon said input circuits and to impress the waves in the third phase upon the common branch of said input circuits.

7. The combination with a system for transmitting three-phase signaling waves, of a repeater comprising a pair of amplifying devices, means for impressing waves in all three phases on the input of said repeater, and means associated with the output of said repeater to derive three equal electro-motive force components having a mutual phase relation of 120 degrees.

8. The combination with a system for transmitting three-phase signaling waves, of a repeater comprising a pair of amplifying devices having balanced input and output circuits, means for impressing waves in all three phases on said input circuits, means for separately deriving amplified waves in two phases from said balanced output circuits, and means for deriving amplified waves in the third phase jointly from said balanced output circuits.

9. The combination with a system for transmitting three-phase signaling waves, of a repeater comprising a pair of amplifying devices having balanced input and output circuits each including a common branch, means for impressing waves in two phases individually upon said input circuits, means for impressing waves in the third phase upon the common branch of said input circuits, means for separately deriving amplified waves in said first two phases from said balanced output circuits, and means for deriving amplified waves in the third phase from the common branch of said output circuits.

10. The combination with a system for transmitting three-phase signaling waves, of a repeater comprising a pair of amplifying devices having balanced input and output circuits each including a common branch, means for impressing waves in two phases individually upon said input circuits, means for impressing waves in the third phase upon the common branch of said input circuits, and a three-phase transformer having two similar pairs of windings associated with the individual balanced output circuits to transmit amplified waves in said first two phases, and having a third pair of windings including a reversed secondary winding associated with the common branch of said output circuits to transmit amplified waves in the third phase.

11. A three-phase transmission system comprising two line sections adapted for the

simultaneous transmission of power currents and a wide band of signal modulated carrier waves, a three-phase low pass filter connecting said line sections and offering substantially infinite attenuation to the signal modulated waves without interfering with the normal transmission of power currents, a repeater including a pair of amplifying devices having input and output circuits, branch conductors connecting said input and output circuits to the respective line sections on opposite sides of said low pass filter, and three-phase filters in circuit with said branch conductors to transmit selectively certain of said signal modulated waves and to prevent the power currents from entering the repeater.

In witness whereof, I hereunto subscribe my name this 29th day of April A. D., 1926.

FRANCIS X. RETTENMEYER.