

Feb. 7, 1939.

E. PETERSON

2,146,091

HARMONIC PRODUCING APPARATUS

Filed April 9, 1938

FIG. 1

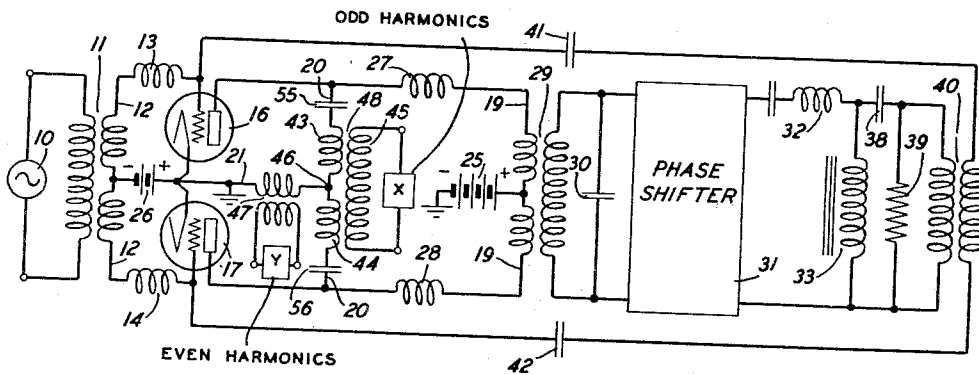


FIG. 2

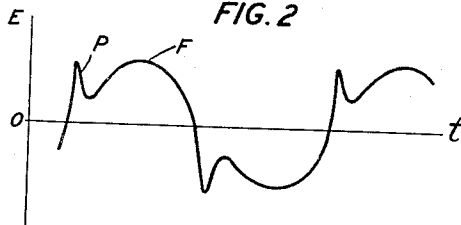
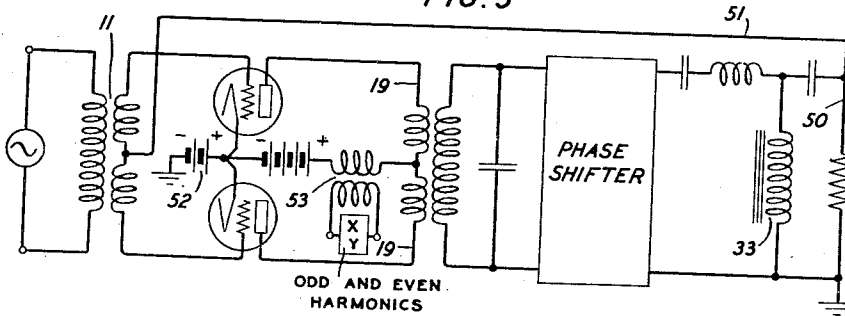


FIG. 3



INVENTOR
E. PETERSON
BY *H. A. Burgess*
ATTORNEY

UNITED STATES PATENT OFFICE

2,146,091

HARMONIC PRODUCING APPARATUS

Eugene Peterson, New York, N. Y., assignor to
Bell Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

Application April 9, 1938, Serial No. 201,052

6 Claims. (Cl. 171-97)

This invention relates to harmonic producing apparatus, and more particularly to a device for producing both odd and even harmonics.

It is well known that a fundamental frequency of alternating current can be distorted in suitable apparatus of magnetic or thermionic type to produce harmonics thereof. In this connection the copending application of L. R. Wrathall, Serial No. 77,989, filed May 5, 1936, now Patent No. 2,117,752, dated May 17, 1938, discloses a system utilizing a non-linear inductance for producing from a fundamental current a desired range of odd harmonics having uniformly large amplitudes extending over the entire range. In this system a copper-oxide bridge is employed to rectify odd harmonics to obtain even harmonics of the fundamental current.

It is an object of the invention to provide means for simultaneously producing ranges of odd and even harmonics both of which have uniformly large amplitudes extending over the entire ranges.

It is another object of the invention to produce a wave pattern that includes fundamental current and a range of harmonics thereof.

It is still another object of the invention to produce a wave pattern comprising fundamental current and odd harmonics thereof both of which are applied to a single apparatus which amplifies the fundamental current and effects both odd and even harmonics of the initial odd harmonics.

In one embodiment the invention comprises a source of fundamental current coupled to a pair of three-element thermionic tubes whose output comprises a pair of divided circuits in parallel and a common circuit. One divided output circuit is coupled to a non-linear inductance for applying amplified fundamental current thereto. The output of the non-linear inductance comprising a capacity and a resistance in series for producing a series of relatively sharp pulses is coupled to the thermionic tubes so as to superpose the sharp pulses on the fundamental current. A phase shifting network included in the coupling of the thermionic tubes to the non-linear inductance serves to so shift the phase of the amplified fundamental current that a wave pattern applied to the thermionic tubes is such that the sharp pulses preferably lead the fundamental current by substantially 90 degrees. The other divided output circuit is connected to a work circuit adapted to select odd harmonics of the fundamental current while the common output circuit is connected to a work circuit adapted to select even harmonics of the fundamental current.

The invention will be more readily understood from the following description taken together with the accompanying drawing in which:

Fig. 1 is a diagrammatic circuit illustrating one embodiment of the invention;

Fig. 2 is a wave pattern produced in accordance with the invention and utilized in Figs. 1 and 3; and

Fig. 3 is also a diagrammatic circuit showing an alternate embodiment of the invention.

Referring to Fig. 1 a generator 10 of alternating current of fundamental frequency is connected to the primary of a transformer 11 whose secondary at the opposite ends is applied to divided input circuits 12, 12 including inductances 13 and 14 to the grids of a pair of three-element thermionic tubes 15 and 17 having an output comprising divided circuits 19, 19 and 20, 20 in parallel and a common circuit 21. The filaments of the thermionic tubes are preferably heated from suitable batteries while the anodes are energized by battery 25.

The potential or biasing battery 26 applied to the grids of the thermionic tubes at the mid-point of the secondary winding of the transformer 11 is of such magnitude that the flow of output current is reduced to a relatively low amount during intervals of no grid excitation voltage. With the arrangement of the secondary winding of the transformer 11, described above, alternating potential supplied by the generator 10 is impressed simultaneously on each of the grids but in opposite phase.

The divided output circuit 19, 19 includes inductances 27 and 28 together with the primary winding of a transformer 29 whose secondary shunted by a condenser 30 is applied through a tuned circuit 32 to a non-linear inductance 33. The output of the latter comprising a condenser 38 and resistance 39 connected in series is coupled by transformer 40 and condensers 41 and 42 to the grids of the thermionic tubes. The non-linear inductance together with associated input and output circuits is disclosed in the copending application of L. R. Wrathall, supra.

The divided output circuit 20, 20 comprises primary windings 43 and 44 of a broad band transformer 48 whose secondary winding 45 is applied across a work circuit X. Associated with the primary windings 43 and 44 are the respective blocking condensers 55 and 56 for isolating the amplified fundamental current from the output circuit 20, 20. The mid-point 46 of the primary windings 43 and 44 is connected to the filaments of the thermionic tubes by means of

the common circuit 21 which includes the primary of a transformer 47 whose secondary winding is applied across a work circuit Y. The work circuits include suitable filters for selecting harmonics of the fundamental currents produced in a manner that will be subsequently described.

In the operation of the above-explained circuit shown in Fig. 1 the fundamental current produced in the generator 10 is amplified in the thermionic tubes and thereafter applied through the transformer 29 to the non-linear inductance. As pointed out in the copending application of L. R. Wrathall, supra, the output of the non-linear inductance is proportioned to cause therein the production of a series of sharp pulses, one sharp pulse occurring during each half-cycle of the fundamental current. These sharp pulses producing a desired range of odd harmonics having uniformly large amplitudes are then fed back to the transformer 40 and condensers 41 and 42 through the grids of the thermionic tubes to be superposed on the fundamental current. The inductances 13 and 14 serve to preclude the harmonic energy due to the sharp pulses from passing into the input circuit 12, 12 while the condensers 41 and 42 restrict current of the biasing battery 26 to the grid circuits of the thermionic tubes. Due to the arrangement of the thermionic tubes, the divided output circuit 20, 20 combines harmonic output energy in a differential manner so that odd harmonics of the fundamental current are made available through the work circuit X while the common output circuit 21 combines harmonic energy in an additive manner to make available to the work circuit Y even harmonics of the fundamental current.

In accordance with this invention a phase shifting network 31 is connected in the input of the non-linear inductance, that is, between the secondary winding of the transformer 29 and tuned circuit 32. The constants of this phase shifting network are so proportioned that the amplified fundamental current impressed on the non-linear inductance is shifted 90 degrees. This causes a corresponding phase shift of the sharp pulses superposed on the fundamental current. Consequently the sharp pulses may be leading or lagging the fundamental current by 90 degrees.

In the present case, it is preferred for the efficient operation of the system that the constants of the phase shifting network be proportioned so that the sharp pulses lead the fundamental current by substantially 90 degrees when both are simultaneously applied to the thermionic tubes. A wave pattern of this type is shown in Fig. 2 in which it is seen that the peaks of the sharp pulses P and fundamental current F are substantially of the same magnitude and sign although occurring at different time intervals. As previously mentioned, the output of the thermionic tubes is arranged to effect therein both odd and even harmonics from the odd harmonics due to the sharp pulses while at the same time passing amplified fundamental current to the non-linear inductance for the purpose of producing these sharp pulses. Consequently, a single thermionic device is utilized both for amplifying the fundamental current and distorting harmonics thereof. The inductances 27 and 28 serve to prevent harmonic energy from passing into the primary of the coupling transformer 29.

Fig. 3 is similar to Fig. 1, except the output circuit 50 of the non-linear inductance 33 is connected through leads 51 to the mid-point of the secondary winding of the transformer 11. Now,

the potentials of the fundamental and harmonic currents are simultaneously applied to the grids of the thermionic tubes but in opposite phase. In other words, the fundamental and harmonic currents are differentially applied to the thermionic tubes. In addition, biasing battery 52 impressed on the filaments of the thermionic tubes is of such magnitude that the flow of output current is reduced to a relatively small amount with no grid excitation voltage, and inductances 13 and 14 in the amplifier input 12, 12 (Fig. 1) together with the inductances 27 and 28 in the divided output 19, 19 (Fig. 1) are omitted.

In Fig. 3 the constants of the phase shifting network are so proportioned that the wave pattern applied to the grids of the thermionic tubes is identical with that shown in Fig. 2. In this case, however, both odd and even harmonics of the fundamental current are supplied to a work circuit X, Y connected across the secondary winding of a transformer 53 whose primary winding is connected in the filament-plate circuits of the thermionic tubes. The work circuit includes suitable filters for selecting the odd and even harmonics.

While the invention is particularly described with reference to a circuit utilizing a non-linear inductance for producing sharply peaked waves, it is not necessarily limited thereto as it is equally applicable to a circuit employing any suitable means for producing sharply peaked waves. In this connection, such means would, for example, include gaseous discharge devices, thyrone, copper-oxide, each having a non-linear characteristic. Consequently, it is understood that the invention is capable of modifications other than those disclosed herein, and the scope thereof together with such modifications is defined in the appended claims.

What is claimed is:

1. In a harmonic producing system including a source of fundamental current, an amplifying and distorting device having an input and an output, means for coupling the fundamental source to the input of the amplifying and distorting device, a non-linear device, means for coupling the output of the amplifying and distorting device to the non-linear device for impressing amplified fundamental current thereon, an output circuit for the non-linear device including a condenser and resistance in series both of which are proportioned to produce a series of relatively sharp pulses and thereby odd harmonics of the fundamental current, means for connecting the output of the non-linear device to the amplifying and distorting device to superpose the sharp pulses on the fundamental current, means included in the output of the amplifying and distorting means for effecting therein odd and even harmonics of the fundamental current, means consisting of a phase shifting network for so adjusting the phase of the amplified fundamental current applied to the non-linear inductance that the wave pattern impressed on the amplifying and distorting device comprises sharp pulses and fundamental current both of which have peaks of substantially the same magnitude and of the same sign.

2. In a harmonic producing system including a source of fundamental current, an amplifying and distorting device having an input and an output, means for coupling the source to the input of the amplifying and distorting device, a non-linear device, means for coupling the output of the amplifying and distorting device to the non-linear device for applying amplified fundamental current thereto, an output circuit for the non-linear

device including a condenser and a resistance series both of which are proportioned to produce a series of relatively sharp pulses and thereby odd harmonics of the fundamental current, means for coupling the output of the non-linear device to the amplifying and distorting device to superpose the sharp pulses on the fundamental current, work circuits, means included in the output of the amplifying and distorting device to differentially and additively connect the work circuits thereto for respectively producing therein odd and even harmonics of the fundamental current, means comprising a phase shifting apparatus for so adjusting the phase of the fundamental current that the peaks of the sharp pulses and fundamental current applied to the amplifying and distorting device occur at different time intervals.

3. The harmonic producing system according to claim 2 in which the constants of the phase shifting apparatus are so proportioned that the peaks of the sharp pulses and fundamental current are of the same sign.

4. The harmonic producing system according to claim 2 in which the constants of the phase shifting apparatus are so proportioned that the peaks of the sharp pulses and fundamental current are of the same sign and of substantially the same magnitude.

5. The harmonic producing system according to claim 2 in which the constants of the phase shifting apparatus are so proportioned that the phase

of the amplified fundamental current is shifted 90 degrees.

6. In a harmonic producing system including a source of fundamental current, an amplifying and distorting device, means for differentially connecting the fundamental source to the amplifying and distorting device, a non-linear device, means for coupling the output of the amplifying and distorting device to the non-linear device for applying amplified fundamental current thereto, an output circuit for the non-linear device including a condenser and resistance in series both of which are proportioned to produce a series of relatively sharp pulses and thereby a range of odd harmonics of the fundamental current, means for connecting the output circuit of the non-linear device to the differentially connected means for superposing sharp pulses on the fundamental current, a work circuit, means included in the output of the amplifying and distorting device for supplying to the work circuit odd and even harmonics of the fundamental current, means comprising a phase shifting network for so adjusting the phase of the amplified fundamental current applied to the non-linear inductance that the wave pattern applied to the amplifying and distorting device consists of sharp pulses and fundamental current whose peaks are of the same sign, substantially of equal magnitude and occur at different time intervals.

EUGENE PETERSON.