

July 15, 1924.

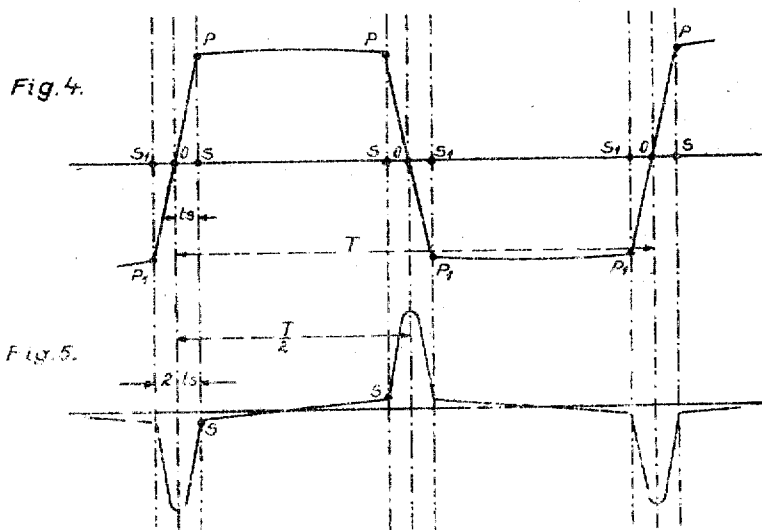
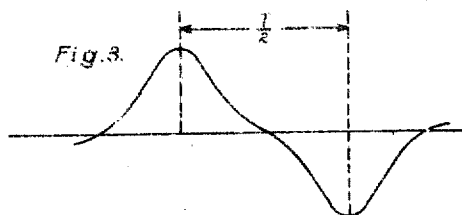
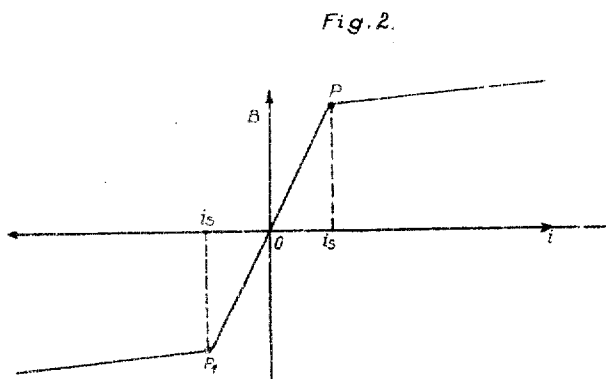
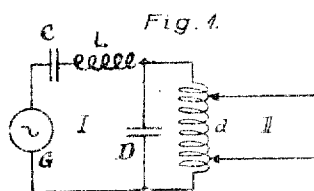
1,501,569

M. OSNOS

FREQUENCY MULTIPLIER SYSTEM

Filed Aug. 8, 1922

2 Sheets-Sheet 1



Inventor
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Fig. 6.

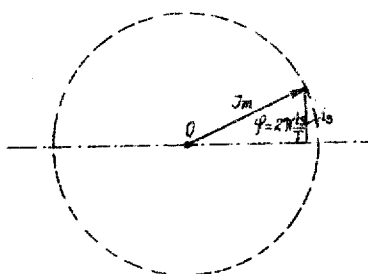


Fig. 7.

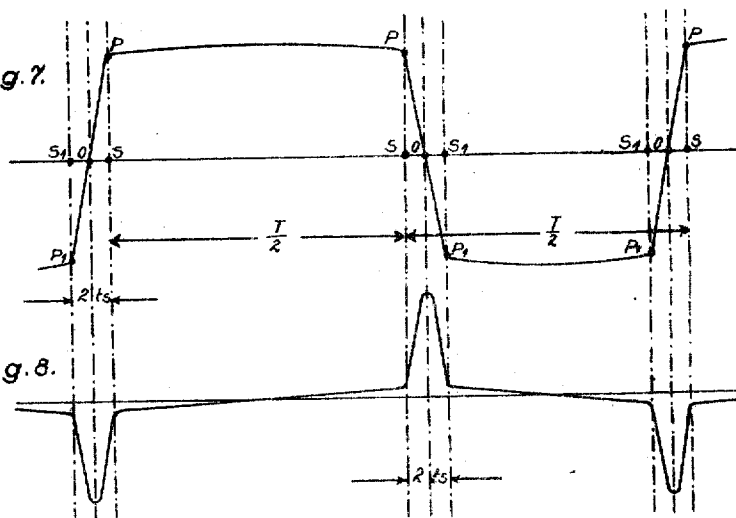


Fig. 8.

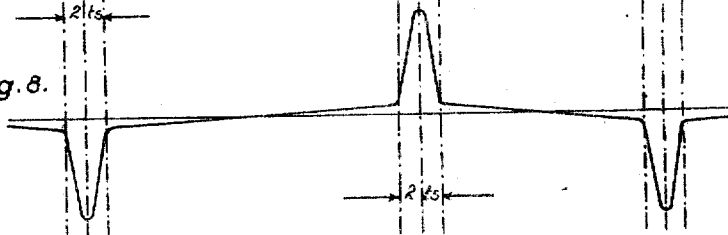
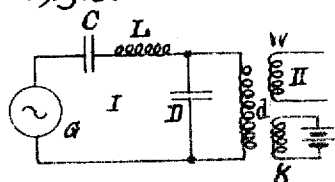


Fig. 9.



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UNITED STATES PATENT OFFICE.

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FREQUENCY-MULTIPLIER SYSTEM.

Application filed August 8, 1922. Serial No. 580,521.

To all whom it may concern:

Be it known that I, MENDEL OSNOS, a citizen of Russia, residing at 12/13 Hall-
esches Ufer, Berlin, Germany, have invent-
ed certain new and useful Frequency-Multi-
plier Systems, of which the following is a
specification.

As evidenced by the work of Steinmetz—
"Theorie und Berechnungen der Wechsel-
stromerscheinungen" (Theory and calcula-
tions of phenomena of alternating cur-
rents), Berlin 1900, pages 118 to 123 inclu-
sive, and German Patent, 286,531, it has
heretofore been proposed to produce by
means of highly saturated iron reactances in
addition to a given basic frequency, still
higher frequencies. In such a case, how-
ever, several frequencies of substantial am-
plitudes, arise simultaneously, whereas gen-
erally only one of them is desired.

The present invention makes it possible
to produce the desired higher frequency in
a particularly pure state. According to the
invention, this is achieved by so choosing
the size of the reactance and especially the
ratio of the current feeding the reactance
(or of the corresponding ampere turns) to
the saturation current (or to the ampere-
turns serving to achieve the saturation
point) that the time during which the mag-
netization of the reactance rises from zero
to a sufficiently high value, i. e. to the so-
called knee of the saturation curve, is to
the duration of one fourth period of the
fundamental wave of the alternating cur-
rent as 1 is to n , in which n denotes the de-
sired multiple of frequency.

The operation of my invention will be
understood from the following description
when considered with the accompanying
drawing, in which:

Fig. 1 shows a circuit by means of which
my invention may be practiced.

Figs. 2, 3, 4, 5, 6, 7 and 8 are diagrams ex-
plaining the theory and operation of my
invention.

Fig. 9 shows a modified circuit by means
of which my invention may be practiced.

A reactance d , Fig. 1, may be fed from
the generator G over the circuit I with a
basic frequency and may itself transmit the
desired higher frequency to a correspond-
ingly syntonized secondary circuit II.

In the circuit I there may be arranged in
series with the reactance d regulating de-
vices such as variable syntonizing or tuning
means, i. e. an inductance L in series with a
capacity C , which causes the current pro-
duced by the generator to follow, so far as
possible, a sine wave form. Furthermore,
for relieving the generator from the watt-
less current or for purposes of stabilization,
a device, such as a condenser D , may be
used in parallel with the generator.

Since these regulating devices are used
to keep the current flowing thru the react-
ance d sinusoidal and the counter E. M. F.
set up by the reactance is non-sinusoidal
(due to the phenomena on which this inven-
tion is based) the applied voltage across the
reactance d is also non-sinusoidal. The gen-
erator G generates a sinusoidal voltage so,
therefore, in order for the sum of the volt-
age drop across the reactance d and the
voltage drop across the regulating devices
should at all times be equal the generator
voltage, the voltage drop across the regulat-
ing devices must be non-sinusoidal. The sec-
ondary circuit II fed with the desired high-
er frequency may be connected, as shown,
directly to the iron saturated reactance d ,
for instance to certain intermediate wind-
ings or outer windings or coupled with the
iron reactance inductively by means of a
secondary winding W , Fig. 9.

In the following, it will first be assumed
that the plant runs without load, in which
case the current J sent by the machine into
the iron reactance may be assumed to be
sine-shaped. If the iron reactance has no
direct current ampere-turns, its ampere
turns are proportionate to its alternating
current and, if no consideration is taken of
the hysteresis, its magnetization B alters in
accordance with its magnetization curve,
Fig. 2. In consequence of this flux-variation,
an electro-motive force is induced in the
reactance which, in case the current is of
sine-wave form, follows generally, as is well
known, the course shown in Fig. 3, again
assuming that the influence of hysteresis is
not considered. The voltage curve according
to Fig. 3 contains, in addition to the
fundamental frequency various higher
harmonics of which, however, only a single
one is needed as a useful wave. This

harmonic is, as a rule, not sufficiently pronounced.

If conditions are chosen according to the invention, a voltage curve is obtained which has the desired, useful high harmonic very pronounced, while the others are almost completely suppressed. If, for instance, it is desired to use the fifth harmonic for a useful wave, then, according to the invention, the conditions are so chosen that the voltage curve has the course shown in Fig. 5. The characteristic feature of this curve is that at first it follows the course of a negative half-wave, the period $2t_s$ of which constitutes fairly accurately the fifth part of half the period T of the first harmonic, and that with regard to shape it follows very closely the required sine-shaped half wave of the fifth harmonic. Then the curve alters very little for a long time, after which it forms a positive half-wave, which is of like period to the preceding negative half-wave and is apart from the latter by exactly $\frac{T}{2}$ and therefore able to support it with regard to its effect.

For producing this voltage curve of a favourable shape, it is necessary that the field changes very quickly between points S_1 and S as is shown in Fig. 4, and that the voltage between the points S, S remains small. The field must alter very little during this time, that is to say, the values of the magnetization curve, Fig. 4, between the points P, P must be at strong saturation (above the knee). The part P_1-P of the magnetization curve, however, denotes a range of strong alteration, but of less magnetization. Thus the amounts of the induction B at the points P_1-P , Fig. 4, must correspond to the knee-points P_1 and P of the magnetization curve, Fig. 2, and the time t_s , Figs. 4 and 5, must be the one during which the magnetization of the reactance rises from zero to the knee value.

Now according to the foregoing in the given case, that is, for the production of the fifth harmonic, $2t_s$ must amount to one fifth of the time $\frac{T}{2}$ which is half of the basic period. Accordingly,

$$2t_s : \frac{T}{2} = 1 : 5 \text{ or } t_s : \frac{T}{4} = 1 : 5.$$

In an analogous manner, for the general case of an n -times increase of frequency, the condition is obtained:

$$t_s : \frac{T}{4} = 1 : n \quad (1)$$

Thus the condition for the n -times increase of frequency can be expressed as follows: The time t_s during which the magnetization of the reactance rises from zero to a sufficiently high value, that is, the knee-

point, must be to $\frac{1}{4}$ period of the first harmonic, that is, the basic frequency as $1 : n$.

The above condition also furnishes the formula for the relation between the momentary value i_s of the current which produces the saturation point, this current being sometimes briefly referred to hereafter as the "saturation current," and the value of the amplitude J_m of the alternating current sent by the generator into the reactance. This is obvious from the vector diagram, Fig. 6, in which i_s is the momentary value of the current at the time t_s with an amplitude J_m and a time period T . It is thus true:

$$i_s = J_m \sin 2\pi \frac{t_s}{T} \quad (2)$$

Equating formula (2) with formula (1):

$$i_s = J_m \sin \frac{\pi}{2n} \quad (3)$$

From equation (3), the saturation current can be calculated if the desired multiple of frequency n and the maximum current flowing through the reactance are given, and from this current again the cross sectional area of the iron core of the reactance and the necessary number of turns in the windings of the reactance can be ascertained.

If reversedly, the dimensions of the iron core of the reactance, the number of turns in its windings, and thus also the saturation current are given, with equation (3) the maximum current required for obtaining an n -times increase of frequency can be calculated.

The above described conditions also hold good approximately in cases when a load is put on or when the primary current departs slightly from the sine-shape.

If the desired multiple n of the frequency is greater than 2, in the equation (3) the sine of $\frac{\pi}{2n}$ can be replaced by the angle itself $\frac{\pi}{2n}$ with sufficient approximation whereby the following simple relation is obtained:

$$J_m \cong i_s \frac{2}{\pi} \cdot n \quad (4)$$

If the iron reactance is used without direct current magnetization as in the aforedescribed example, the currents i_s and J_m flow generally through one and the same windings. In case, however, direct current magnetization is employed as illustrated in Fig. 9, the saturation current is caused to flow through windings K different from the alternating current windings. In this case, in place of the currents the corresponding ampere turns are put into the equation (3) or (4). Then in these equations, i_s and J_m denote ampere turns.

If the iron reactance be magnetized

by means of direct current an even, for example, a six-fold increase of frequency is to be produced. If the abscissa in Fig. 2 now represents the direct current ampere turns which produce the necessary saturation of the reactance, the value of the alternating current ampere turns can be calculated from the formula (3) or (4) respectively and for the reactance a field-curve with the momentary course of the induction according to Fig. 7 is obtained from which results the voltage curve according to Fig. 8.

As the alternating current at the knee points is in this case equal to zero, the length s , s in Fig. 7 represents the time between two passages of the alternating current through zero, i. e. $\frac{T}{2}$, which denotes half of the basic period. The points O of the curve, Fig. 7, correspond to the points at which the direct current- and alternating current ampere turns neutralize each other so that the induction is zero, and the points S_1 represent those moments in which the induction passes through the knee-values P_1 of the negative part of the magnetization curve. The periods $S, S=2t$, are again the periods of the intensive alteration of the induction, the periods s, s and s_1, s_1 being the periods of small alteration.

The time $2t$, is in Fig. 8 one sixth of the time $\frac{T}{2}$ (corresponding to the desired sixfold frequency) and the positive half-wave of a sixfold frequency is moved to the right in such a manner with regard to the middle position between two negative half waves of a sixfold frequency that the positive and negative half-waves support each other with regard to their effect on the started oscillation of a sixfold frequency.

This shows that also in this case the condition stated above for the reactance without the direct current excitation is fulfilled, as also here the time $OS=t$, Fig. 7, during which the flux rises from zero to a sufficiently great value to saturate the core and amounts to one n th, that is, in the case assumed to

one sixth part of the time $\frac{T}{2}$.

I claim as my invention:

1. An alternating current system comprising a highly saturated iron reactance, a secondary circuit for withdrawing current from the reactance and means for supplying current to the reactance, the reactance being of such size and the means for supplying the current to the reactance being so constituted that the time required for the magnetization of the reactance to rise from zero to the knee of the saturation curve is to the time of one-fourth period of the basic wave of the alternating current system substantially as 1 is to the desired multiple of the basic frequency, substantially as described.

2. An alternating current system for increasing frequency by means of a highly saturated iron reactance, which comprises a reactance of such size and means for supplying current to the reactance in such ratio that the time required for the magnetization of the reactance to rise from zero to the so-called knee of the saturation curve is to the time of one-fourth period of the basic wave of the alternating current system substantially as 1 is to the desired multiple of the basic frequency, substantially as described.

3. An alternating current system for increasing frequency by means of a highly saturated reactance, comprising a reactance with an alternating current winding and a direct current winding, and means whereby the value of the magnetization caused by the direct current winding is at the knee of the magnetization curve, and means whereby the ratio of the time required for the magnetization to change from zero to the knee of the magnetization curve is to the time of one fourth of the period of the basic alternating current wave substantially as one is to the desired multiple frequency, and means for utilizing said multiple frequency.

In testimony whereof I have signed my name to this specification.

MENDEL OSNOS