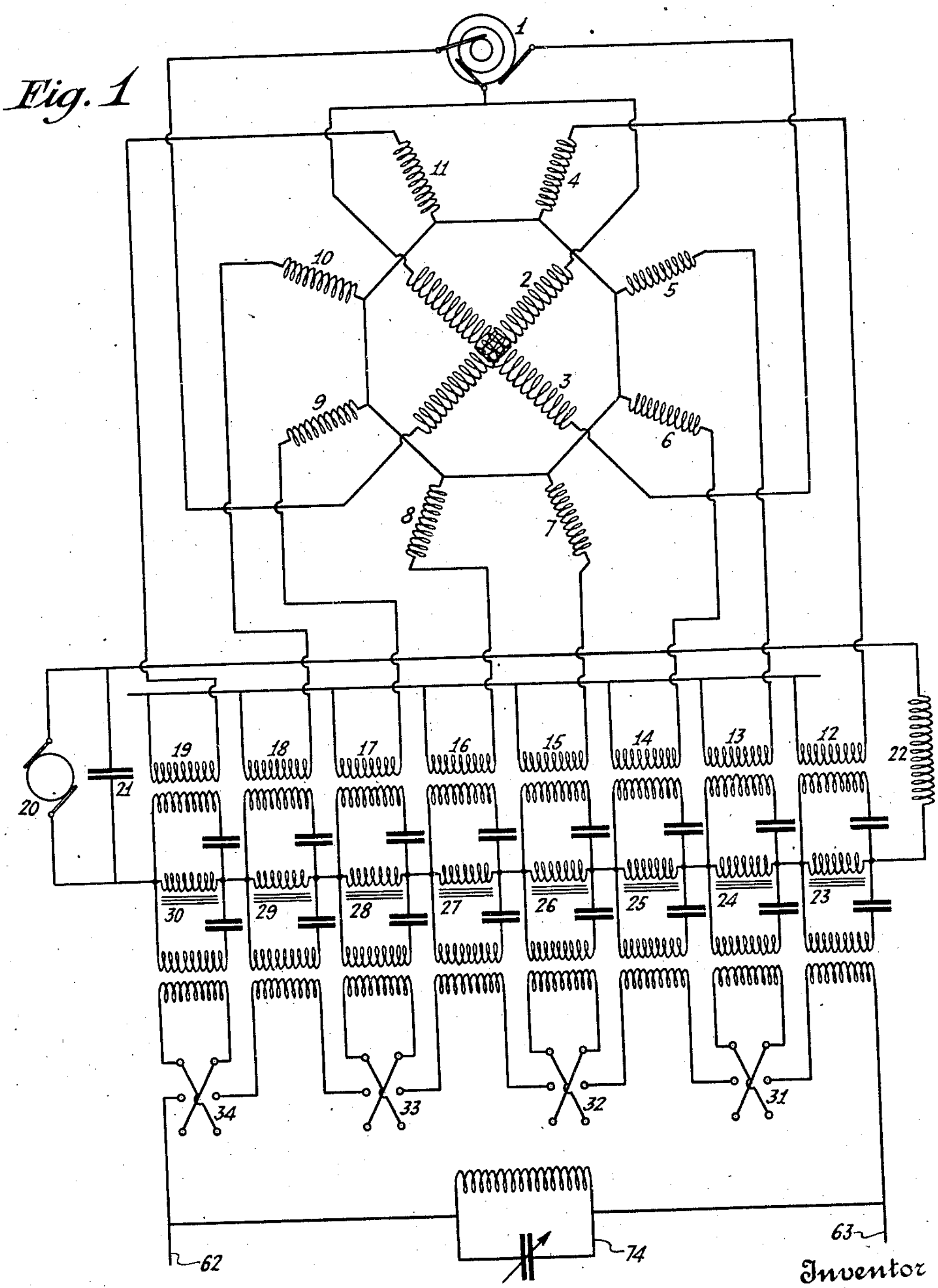
Jan 6, 1931. N. E. LINDENBLAD 1,787,948

IRON CORE STATIC FREQUENCY CHANGER

Filed March 2, 1927 3 Sheets-Sheet 1

Fig. 1

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Filed March 2, 1927 3 Sheets-Sheet 2

*Fig. 2*

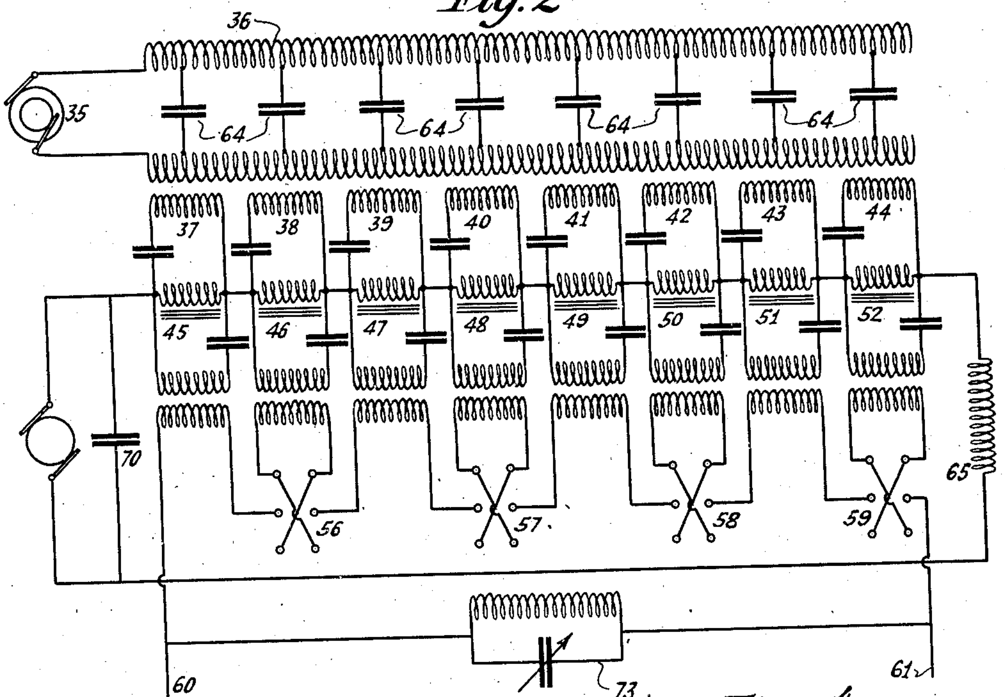



*Fig. 3*

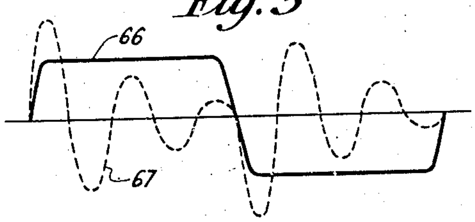



*Fig. 4*

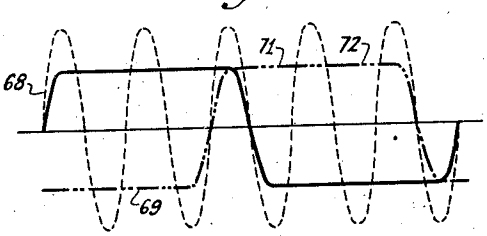
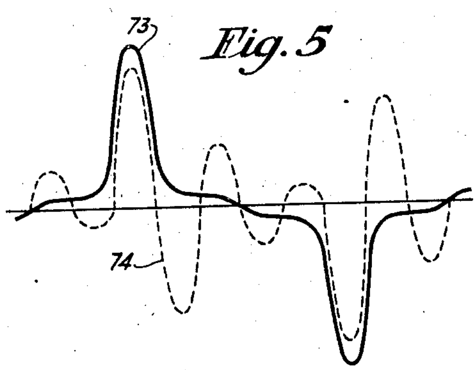



*Fig. 5*

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Filed March 2, 1927 3 Sheets-Sheet 3

*Fig. 6*

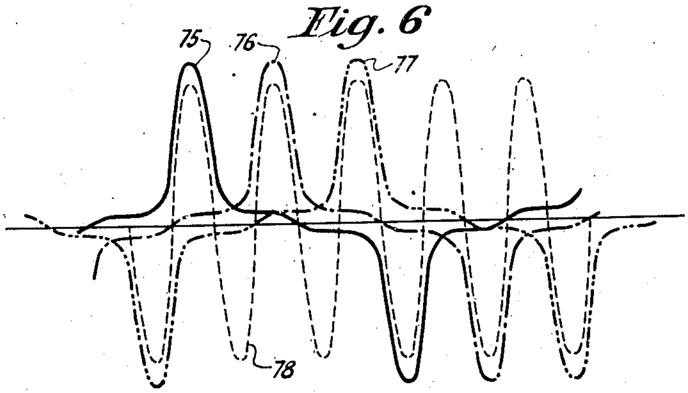
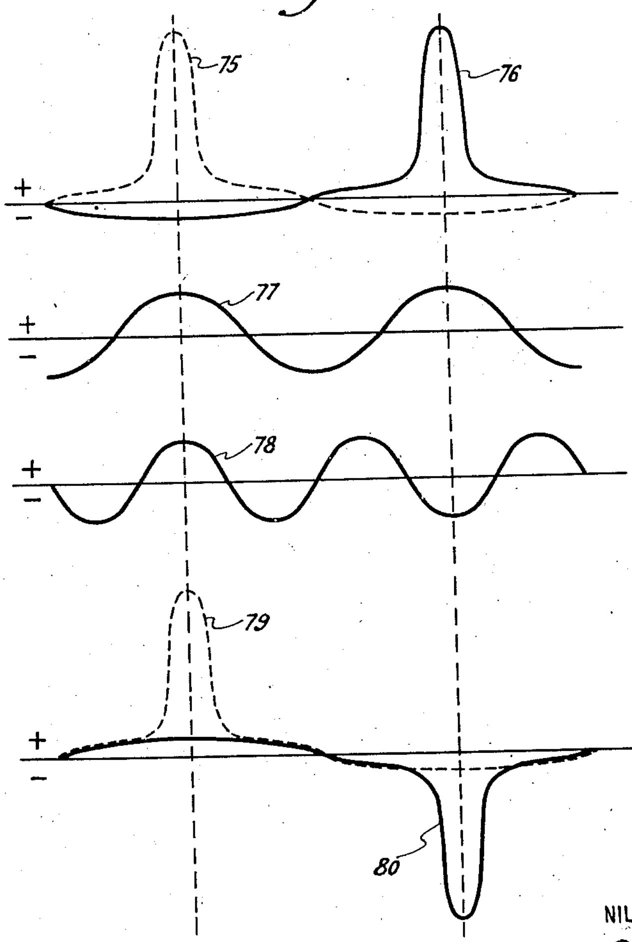



*Fig. 7*

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# UNITED STATES PATENT OFFICE

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## IRON-CORE STATIC FREQUENCY CHANGER

Application filed March 2, 1927. Serial No. 172,140.

This invention relates to iron core static frequency changers. It has for its objects the simplification, improvement in efficiency and increased ease of construction over other forms of devices of the same character.

It has been often demonstrated in the construction of iron core frequency changers used to form the basis of apparatus designed for frequency multiplication that only a small increase in frequency is possible with a single transformer. This invention relates to a method whereby a greater overall efficiency may be obtained and a high multiplication of frequency in a single transformer unit is obtained.

The usual method of obtaining frequency change with iron core devices is by the use of simple wave distortion. My device relates more specifically to the use of what may be called shock excitation and many difficulties which arise in the application of this shock principle are obviated by this invention.

The principal difference between the ordinary wave distortion method and the shock excitation method of operating frequency multipliers is in the degree of saturation given to the iron core which forms the transformer base.

The ordinary characteristic curve of any particular sample of iron or other ferrous metal has a fairly continuous slope over a certain part and then bends over at the top rapidly. From this bent over portion or knee, as it is commonly called, the curve more nearly approaches the characteristic curve of air without any metallic core. In the single wave distortion method, saturation is carried fairly well up on the first part of the curve to a point just below the knee. In this case any change of current in opposition to the saturation will cause considerable change in flux, while current in an additive direction will cause a slight change up to the top of the knee and from there on will cause lesser change. It is this feature which gives the wave of current in the additive direction a distorted or flat top. Of course, in practical applications, two cores may be used if it is desired that both the upper and lower half of the wave be effective.

In the shock excitation method the saturation is carried considerable distance above the knee of the curve so that current in additive direction to the original magnetizing current will cause little or no change in flux while current in an opposing direction to the original excitation will cause little change until the number of ampere turns opposing the original excitation reaches that sufficient to carry the total flux over the knee of the curve and down the straight portion. Thus, it will be seen that a change will occur only when the steeper part of the alternating current wave which is passing through the primary connections of the changer is reached and from this we get the term "shock", indicating that the effective part of the fundamental wave is in the form of a shock or sudden application of current. If the original excitation was such as to cause the iron to be saturated to a point directly at the knee of the curve, then no shock would result inasmuch as the gradually sloping sides of the fundamental would cause as much effect in relation to their slope as would the more peaked portion. It has been found that this shock excitation method is the most practical and efficient for all purposes.

Where a single frequency is used to excite a transformer core designed to develop a high ratio of output to input frequency, considerable difficulty results from the attenuation of oscillation between single shocks produced by each wave. There are several methods which have been applied to overcome this objection. However, the methods heretofore used have all been found to be more or less disadvantageous. This invention relates to an improved method of increasing the number of shocks per cycle of input frequency.

This result is obtained in general by the use of multi-phase alternating current excitation and several methods are herein disclosed for applying it. The most advantageous operation has been found by actual experience to result with use of a separate shock for each cycle of output frequency.

One method of doing this is to use a phase rotator and another is to use an artificial line which can be tapped at as many points and phase angles as desired. By this method no change is necessary in present type alternator construction, but a newly designed type of phase rotator or artificial line is necessary.

A further object of my invention is to permit of selection of any desired harmonic which is either an even or an odd multiple of the number of pairs of phases employed for excitation.

Further and more definite objects may appear in connection with the following specification, claims and drawings in which:

Fig. 1 shows a phase rotator method.

Fig. 2 shows an artificial line method.

Fig. 3 shows the relation of input to output frequencies in a single wave distortion frequency changer.

Fig. 4 shows the relative relation in the present type.

Fig. 5 shows the relation of input to output frequencies in a single wave "shock" excitation frequency changer.

Fig. 6 shows the same having multi-frequency excitation.

Fig. 7 shows the relation of harmonics.

In Figure 1, 1 is a two or quarter phase alternator having its output connected to the phase rotator coils 2 and 3. In proper relation to these coils are located secondary coils 4 to 11, arranged at equal angles to the phase rotator. Any number of these secondary coils may be used with or without iron cores provided they are spaced in the proper manner. These coils are respectively connected to the transformers 12 to 19 inclusive, which are coupled with the frequency changer units 23 to 30 inclusive. These changers are excited by proper source of direct current 20 which is protected by the choke coil 22 and the condenser 21. The output of these changers is coupled to the circuit 62, 63 through reversing switches 31 to 34 inclusive and the circuit 74 tuned to the desired harmonic. The operation of these switches is to obtain a choice of the harmonics which are the odd or even multiples of half the number of phases employed, as will be more fully explained later.

35 as shown in Fig. 2 is a single phase source of alternating current connected to the artificial transmission line 36 having two inductances capacitively coupled at frequent intervals by condensers 64. It can be readily seen that a difference of phase angle will exist in the current between the relative points along the separate coils of this line. Coupled to this coil at equally spaced intervals are any desired number of coupling coils 37 to 44 inclusive. These are associated with the frequency changers 45 to 52 inclusive, respectively. These frequency changers are energized by a proper source of saturation current 55 protected by choke coil 65 and condenser 70.

The output of these frequency changers is taken off at 60 and 61 through the reversing switches 56 to 59, inclusive, as in the case of Fig. 1 and the circuit 73, by resonance, selectively augments the desired harmonic and to a considerable degree prevents any but the desired harmonic from being taken off.

Ordinarily with a single phase source of excitation for the purpose of producing a relatively high harmonic, as shown in Figure 3, considerable attenuation occurs which is detrimental to the signal. Here 66 shows the fundamental distorted to such an extent that the fifth harmonic is predominant, but this harmonic, as indicated at 67, is attenuated in form. This change in intensity is due to the inherent characteristics of the frequency changer and its associated circuits. However, if multi-phase excitation is used little or no deterioration in intensity between separate shocks of the input frequency results in the output frequency.

An illustrative example of this is shown in Fig. 4 where 69, 71 and 72 are displaced primary exciting waves and 68 shows the resulting fifth harmonic high frequency wave produced thereby. This shows very little decrease in magnitude between successive waves for the obvious reason that a separate impulse is produced for each high frequency wave by fundamentals of different phase displacement. It can be thus readily seen that a simple and effective arrangement is provided for improving the operation of such frequency changers.

To show the relative relations of the ideas embodied in this invention when used with the shock system of excitation, resort may be had to Figs. 5 and 6.

73 shows a peaked portion of the fundamental which has overcome the original excitation to the degree indicated. The secondary or harmonic voltage when placed in effective relation takes the position as shown in curve 74. This shows the proportions when a single phase is used as a fundamental and it will be noted that considerable attenuation is present which cuts down the efficiency of the system.

Curves 75, 76 and 77, Figs. 6 and 7, of the different phases of the multi-frequency source of excitation are used in producing the harmonic indicated at 78. From this it can be seen that greater efficiency is possible and that less loss is due to attenuation or other undesirable modification of the wave form.

While this system of multi-phase excitation is more effective than the single phase method, some care must be taken to obtain the frequency in exactly the correct phase relation and proper values of inductance and capacity in an artificial line must be correctly determined according to known methods. Also, it is desirable to use both halves of the alternating current wave and this is usually done by using pairs of frequency changer windings, as before indicated. If the two frequency changer windings in each pair are connected in direct series so that their outputs will have an additive relation in the same direction, then the harmonics which are even multiples of the number of pairs of windings will be predominant. If they are connected in a relatively opposite direction, then the harmonics which are odd multiples of the number of pairs of windings will be predominant, and the even multiples will be eliminated regardless of the type of tuning circuits used. This is explained in Fig. 7 where 75 and 76 indicate the effect produced on the secondary or output connections of any pair of windings of the frequency changer by the fundamental when the pair is connected in direct series. Assuming the upper ordinates to be positive and the lower ones negative, it can be readily seen that the even harmonics, as indicated at 77, will result, and that the odd harmonics as represented at 78 will be eliminated. This is true because positive values of the fundamental occur at the same point in time as positive values of the even harmonic. In the case of the odd harmonic, the positive peak 78 coincides with 75 but 78 has no positive peak coinciding with 75 and will therefore be eliminated due to the positive reaction of 76.

If, however, the two windings of each pair in the frequency changer are connected to give opposite effects upon the output connections, such effect will be evident in curves 78 and 80 where 79 is positive and 80 is negative. When these two curves are compared with the curves 77 and 78 above, it will be seen that 77 will be eliminated and 78 will be predominant, since the peak values of curve 77 do not coincide with the peaks 78 and 80, while those in curve 78 do. From this it will be seen that harmonics which are an odd or even multiple of the number of pairs of windings can be produced merely by different connections of the frequency changer, and, for this purpose, a series of reversing switches have been provided, as at 31 to 34 of Fig. 1, and 56 to 59 of Fig. 2. With one pair of windings even or odd harmonics may be obtained, but with more than one pair the harmonics will all be even. By proper manipulation of these switches, and coordination with the tuning of the circuits 74 and 73 respectively, any desired harmonic which is either an odd or even multiple of the number of pairs of windings may be obtained. In addition to these adjustments, some change must be made in the original excitation to compensate for wave form.

From this disclosure, it is evident that a system has been devised for producing harmonics of a fundamental frequency which are of stable, unattenuated, and useful character.

This invention is not intended to be limited to the use of direct current auxiliary excitation, for an alternating current excitation may also be used, although it is not so readily manipulated as is the direct current, and the latter type is to be preferred. It is not intended that this invention be limited in extent to the above described arrangement, for different substitutes and combinations may also be used which are within the scope of the following claims.

I claim:

1. In combination, a plurality of pairs of magnetic cores, means for producing magnetization above the knee of their magnetization characteristic, means for energizing the cores with multi-phase alternating current, output coils for each core, and reverse switching means connected to an output coil of each pair to permit selection of harmonics which are odd or even multiples of the number of pairs.

2. In combination, a plurality of pairs of magnetic cores, means for producing magnetization above the knee of their magnetization characteristic, means for energizing the cores with multi-phase alternating current, output coils for each core, reverse switching means connected to an output coil of each pair, and tuning circuit means connected to the coils, so that by switching and tuning, harmonics which are odd or even multiples of the number of pairs may be selected.

3. A frequency changer including a pair of magnetic cores, means to saturate them, means for energizing them at a fundamental frequency, an output circuit, an output coil for each core coupled to the output circuit, and reverse switching means connected between one of said coils and the output circuit to permit of selection of a desired harmonic from among a plurality of possible harmonics.

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