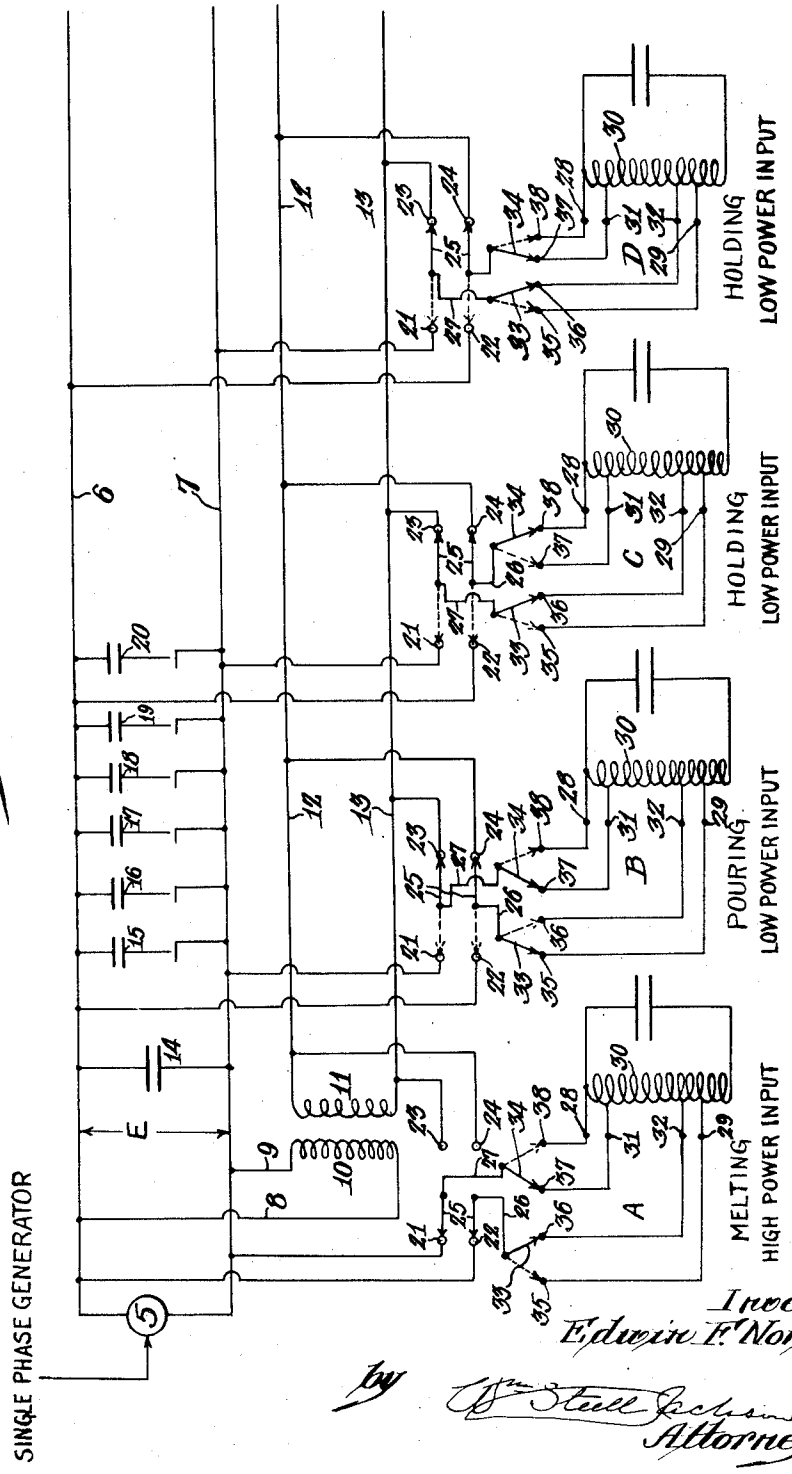
March 15, 1932. E. F. NORTHRUP 1,849,309

INDUCTOR FURNACE FOR PARALLEL OPERATION

Filed March 23, 1928 2 Sheets-Sheet 1

Fig. 1.



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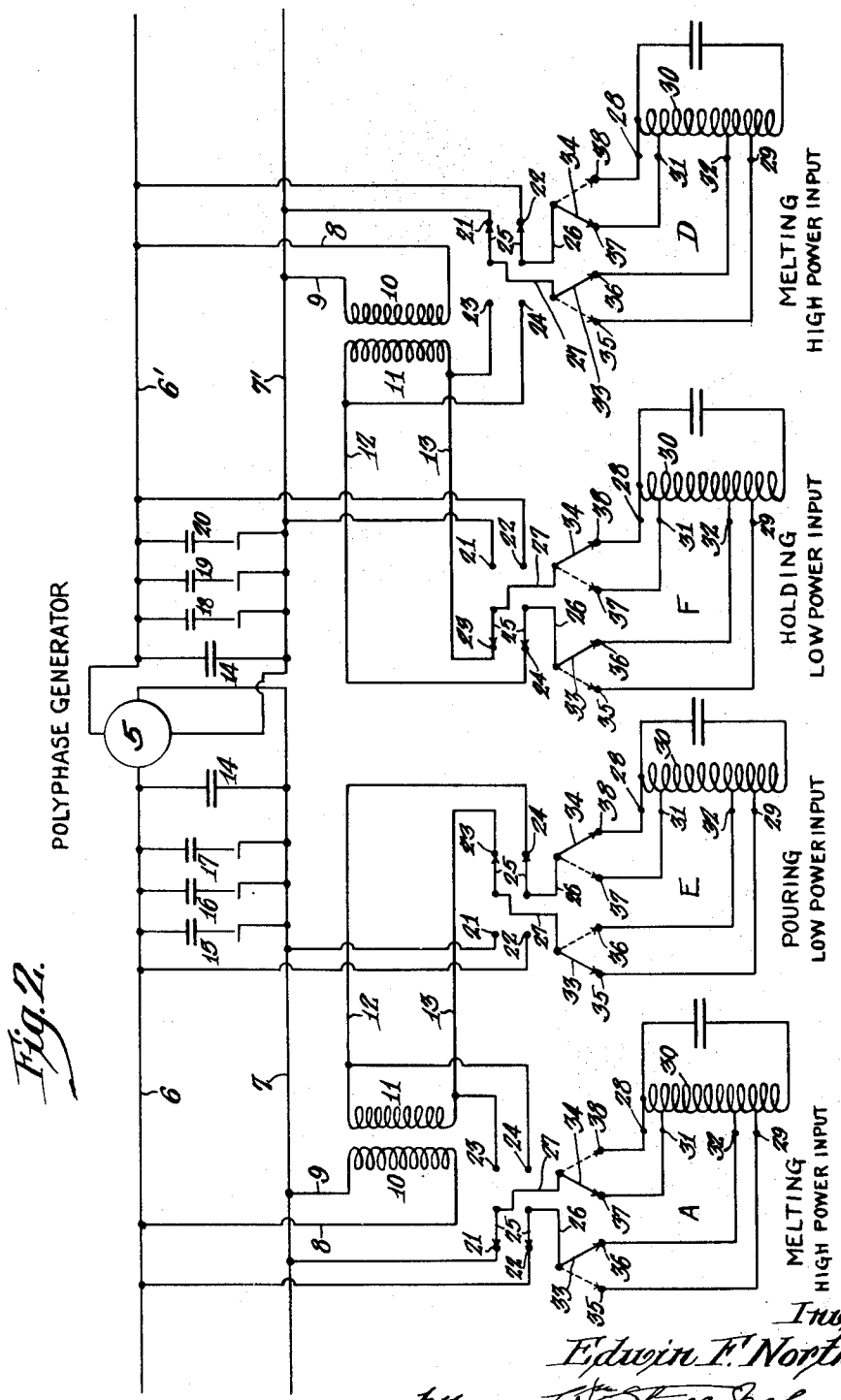


Fig. 2.

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UNITED STATES PATENT OFFICE

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INDUCTOR FURNACE FOR PARALLEL OPERATION

Application filed March 23, 1928, Serial No. 264,195, and in Great Britain May 30, 1927.

This invention relates to the concurrent use of a plurality of electric furnaces from the same generator or from the same mains.

A purpose of my invention is to provide individual rough power factor correction for furnaces with supplemental power factor correction applicable to a plurality of furnaces.

A further purpose is to balance the lagging current to the furnace circuit or circuits of one furnace or of some furnaces against the leading current to the furnace circuit or circuits of another furnace or of other furnaces in order that the difference between the two may be compensated generally for all the furnaces and that the power factors of individual furnaces need not be closely adjusted at the furnaces, the final power factor adjustment being preferably across the mains.

A further purpose is to greatly reduce surging between furnace circuits connected in parallel and to apply the surging current, if any, from it to the furnace coils, preferably at the bottom.

A further purpose is to provide inductor furnaces in parallel with a fixed compensating capacity, to supply the furnaces with current directly from the mains, or alternatively, with current reduced in voltage preferably by transformers and to alter the points of attachment of these alternative voltages of supply as compared with those of the compensating condenser so as roughly to maintain power factor correction at the furnaces and to take care of the differences from exact compensation for all the furnaces at the main circuit.

A further purpose is to avoid surging of current between or among two or more inductor furnaces arranged in parallel by inclusion in power circuit of some turns of either the condenser circuit or some of the inductor windings.

A further purpose is to improve the economy of the system by operating different furnaces or different banks of furnaces from different phases of the same generator supply.

A further purpose is to simplify the connections and economize in the apparatus required for operating a plurality of inductor furnaces in parallel.

Further purposes will appear in the specification and in the claims.

The invention relates to the methods involved as well as to apparatus by which the methods may be practiced.

In the drawings I have preferred to show one only of the various forms in which my invention may appear, selecting a form which is simple, practical, highly efficient and economical and which at the same time well illustrates the principles involved.

Figure 1 is a diagrammatic illustration showing the application of the invention to a plurality of furnaces in parallel.

Figure 2 is a like diagrammatic illustration showing furnaces operated in parallel from different phases of a polyphase generator.

In the drawings similar numerals indicate like parts.

In the operation in parallel of inductor furnaces free from interthreading of furnace iron it has previously been necessary to provide substantially the same character and the same amount of capacity compensation for the inductance in each of the individual furnace circuits as would be required if the furnace circuits were used independently.

This means duplication of the equipment, including duplication of the automatic power factor control and involves the risk of failure of the additional equipment.

There is also opportunity for surging of the current through the connecting line from one furnace to another or to others, involving excessive current flow and excessive heating in the line. Surging may also interfere with the best functioning of the individual furnaces which thus do not get current through their coils which surges to the line.

By altering the connections of the inductor from the generator and by providing alternatively a lower supply voltage I am able so far to adjust to the different conditions of furnace operation during heating up to the recalescence point, heating above the recales-

cence point and melting, holding and pouring as to be able suitably to control the loads supplied to the individual furnaces and at the same time to maintain power factor correction with reasonable closeness by a fixed condenser furnace compensation or, if desired, with a minimum of changes from such fixed connections.

I am able to take care of any variation from accurate power factor compensation in the individual furnace or furnaces partly by balancing the leading condition of one or more circuits against the lagging condition of one or more other circuits and by hand or automatic compensation for the entire group of furnaces at the generator leads.

Where several furnaces are run in parallel there is a real economy in generator construction in dividing the furnace circuits up into groups corresponding in number with the number of phases of polyphase generator and feeding different groups from the different phases of the generator. This causes a substantial saving in material in the generator and therefore in its cost.

Where this benefit is not sought of course single phase generators can be used and so far as the individual feed circuits are concerned they act exactly the same when they are supplied by one phase of a polyphase generator as if they were supplied by a single phase generator. The leading advantage sought in two-phase operation with multiple circuits, one for each set of furnaces, lies in the reduction of cost of the generator.

In Figure 1 I show a generator 5 connected to mains 6 and 7 to which mains a transformer is connected by wires 8 and 9. The transformer is shown as comprisng a primary 10 and a secondary 11, the secondary supplying auxiliary leads 12 and 13.

Across the mains 6 and 7 I show fixed condenser 14 and a plurality of adjustable condensers 15—20 which are adapted for hand adjustment to insert or withdraw them one at a time, or to adjustment by an automatic power factor control mechanism such as is shown in my United States application for method and apparatus for correcting power factor, Serial Number 170,782, filed February 25, 1927.

From the two sources of current, mains 6 and 7 and auxiliary mains 12 and 13, I supply any number of furnaces shown in Figure 1 at A, B, C and D.

In order that the individual furnaces may be supplied with either voltage at will I provide for each of the circuits switch terminals 21 and 22 from the mains, and 23 and 24 from the auxiliary leads 12 and 13. These terminals are connected through a double pole switch 25 with conductors 26 and 27 by which the furnaces are fed.

If these conductors 26 and 27 were directly and permanently attached across the inductor or any part of it, to span, for example, from coil terminal 28 to coil terminal 29 of inductor coil 30, this multiple voltage control alone would give a selection of voltages for application to the furnaces, with corresponding benefit in greater or less current flow according to the voltage applied. However, I secure further selective variation of current flow by the use of taps typified at 31 and 32, so that a part of the coil less than the full length of the inductor may be connected with a current supply of one voltage alone or, preferably, of any of the voltages offered, here illustrated as two.

The number of taps of course may be indefinitely increased. The location of the taps will be determined by the policy of the designer and by the needs of the individual furnace, but in the illustration I have shown the connection 28 as placed at one end of the furnace coil connection, 29 at a point short of the coil end, for a reason later explained, and but two intermediate connections 31 and 32, permitting quite a number of additional variations in the voltage supplied.

The energy input is supplied to the furnace coils through the terminals and taps selectively, through suitable means such as, in the illustration, single-pole, double-throw switches 33 and 34 connecting at one end each with conductors 26 and 27 respectively, and connecting at the other ends of the switch throws alternatively, switch 33 with switch terminals 35 and 36 and hence with coil terminal 29 and tap 32, and switch 34 with switch terminals 37 and 38 and hence with tap 31 and coil terminal 28, respectively.

By the arrangement which is shown an intermediate portion of the coil between taps 31 and 32 is connected in circuit, whatever the position of switch 25, and, though not essential,, this will ordinarily be desirable when the higher voltage is applied in order to have maximum input to the inductor coil. However, in Figure 2, at furnace F, a greater length of coil is connected.

So far as described, the two voltages and 4 switch positions provided permit a considerable variation in the power input to the different furnaces, six of the possible connections being shown in the illustration. In furnace A the switch 25 is connected to supply the higher voltage and the switches 33 and 34 are connected across a minimum of furnace coils supplying a high power input to the furnace such as is suitable for melting at a maximum rate.

In furnaces B, C and D the switch 25 supplies the lower voltage and all of the connections shown span fewer than the maximum of furnace coils. The voltage suits to a low power input such as required for pouring and holding. The three different switch positions shown in these three furnaces, B, C and D, are selected primarily for purposes

of illustration to show that the lower power input can be secured by different selection of the coils in circuit rather than to indicate necessity for different power input. As the taps can be placed at any desired positions great variety of power input is thus made available.

In furnace B the power input spans from coil terminal 29 to tap 31, in furnace C the span is from coil terminal 28 to tap 32, and in furnace D the span shown is from tap 32 to tap 31.

Other combinations are of course available with the two voltages and the two intermediate taps shown. The number of combinations can be correspondingly increased by increase of the number of voltages available, or by increasing the number of taps or by both of these means, greatly increasing the flexibility of the system where this increase is desired.

In all four of the connections shown the power factor correction is thrown across the entire furnace inductor coil and affords average of approximate power factor correction only. If power input leads were also connected to the same points as the condenser leads, there would be a tendency of the circuits to surge between condensers belonging to different furnaces and back into the supply mains. When power input leads are connected to any other points on the inductor coil than where condenser leads are connected, the surging is damped out and does useful work in the furnace load.

It will be obvious that the number of inductor turns between the coil terminals 28 or 29 and the nearer taps may be different in order to additionally control the number of turns of inductor spanned by the generator connections, this change being a matter of furnace design.

The condenser across the furnace circuit provides in effect a current transformer which, with approximate tuning of the circuit, results in a current through the inductor and condenser many times the current supplied by the generator.

Operation of inductor furnaces in parallel across the same mains is open to the serious objection that the condensers used for power factor correction for the different furnaces are also connected in parallel, giving opportunity for surging of current from one circuit to another without passing through the furnace inductor coils. Surging not only robs the inductor coils of the useful current which they are intended to carry, but uselessly throws excessive current upon the connecting mains. The difficulty, therefore, is both real and serious.

I have discovered that by connecting the condensers across a different number of inductor turns than the connection of the power input, the turns spanned by one and not spanned by the other will always be in series with the condenser, and for this reason will always correspondingly protect against surging, thru a damping out of these surges in doing useful work in the heating of the charge.

Though the protection against surging would be approximately the same whether the condensers span merely a different but equal number of inductor turns than the generator supplies or a smaller number or a larger number than they span there is a considerable advantage in connecting the condenser across a larger number of turns than the power input because the voltage upon the condensers will then be higher than the supplied voltage. The smaller the number of turns spanned by the generator supply, the higher will be the voltage upon the condensers and the greater will be the current in the local circuit. At the same time the smaller the number of turns spanned by the generator supply the larger will be the number of inductor turns in series with the condenser between the condenser and the supply connection, and the greater the protection against surging.

By the connection of the condensers across the entire inductor length, with power input spanning a part of the inductor length only, I obtain the usual advantages of a tuned or approximate tuned circuit in increase of current through the circuit, along with the two additional advantages of increase of voltage upon the condensers and of prevention of surging.

The increase of voltage upon the condensers operates condensers at a higher kva. than the kva. of the supply. I find that it is not necessary to closely tune the individual furnace circuits, but that their power factors may be roughly corrected by condensers which approximate the average power factor correction required and which need not ever be altered after being once set. It will be obvious that adjustment of these condensers at intervals to the local needs, though not essential, may be made if desired.

Figure 2 is intended to illustrate the connections of furnaces in parallel across different phases of a polyphase generator. In this illustration the two-phase current has been intended to represent any polyphase current desired, as the same principles apply to three-phase circuits, for example, as to the two-phase form.

In the illustration the mains 6, 7 and 6′, 7′ indicate the phases across which economy of generator construction makes it desirable to connect furnaces.

The diagram at the left corresponds with that shown in the connection of furnaces A and B and that at the right shows two different connections in furnaces E and F, respectively, connected across the mains and auxiliary mains as in Figure 1. The same

reference characters and explanation therefore apply as in the case of the furnace connections in Figure 1. The furnaces shown in the two figures are alike, the differences residing in the connections made.

In these diagrammatic showings it is not intended to restrict to the particular furnaces which may widely differ, nor to the connections shown in the figures, but rather to illustrate that variation in the furnaces and connection and grouping of furnaces is permissible, and that a great many other forms of furnaces and connections of the same come within the general language used but which I have not considered it necessary to separately illustrate.

While my invention finds its greatest utility in the operation of induction furnaces of frequency well above commercial frequencies, the principles involved in it are applicable to induction furnaces of lower frequencies, including commercial frequencies.

It will be evident that the present invention thus provides methods and apparatus for utilizing different phases of the same generator supply and simplifying the individual circuits to reduce the amount and cost of apparatus furnished and to free from the possible sources of failure in the equipment thus saved. I accommodate the demands of the individual furnaces to the best advantage, secure more positive control of power factor in the generator leads where it is most needed, average the current called for in the group of furnaces and the corrective capacity required to the best advantage, and reduce and if desired wholly eliminate surging.

In view of my invention and disclosure variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of my invention without copying the structure shown, and I, therefore, claim all such in so far as they fall within the reasonable spirit and scope of my invention.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:—

1. The method of operating furnaces in parallel from alternating current mains, which consists in partly correcting the power factor of the individual furnace inductor circuits at the furnace and in making further adjustment of the power factor correction of any out-of-phase current component remaining at the mains.

2. The method of controlling energy input to an inductor furnace coil and capacity power factor correction for the furnace, which consists in variantly connecting any of a plurality of different voltages to span alternatively different lengths or portions of the inductor coil, in compensating part of the inductance of the furnace circuit at the coil and in compensating the remainder of the inductance at a different point across the source of energy supply.

3. The method of reducing the power factor corrective capacity required in inductor furnaces free from interthreaded iron, connected in parallel across alternating current mains, which consists in correcting power factor roughly by condensers at the individual furnaces, in connecting the power input across the coils so as to span a smaller number of furnace turns than are spanned by this local condenser power factor correction, omitting in power span part of the lower end of the coil and in making the final power factor correction, for the furnaces in parallel, at the mains.

4. In operation of a plurality of inductor coil furnaces connected in parallel, the method of controlling the input of the furnaces, which consists in varying the number of turns of the inductor coils across which the supply circuit is connected, all above the bottoms of the coils, while protecting from surging from one furnace to another by condenser power factor correction across a different number of inductor turns than are spanned by the supply circuit, including in the condenser span turns below the power connection.

5. The method of reducing the power factor corrective capacity required in inductor furnaces having a frequency higher than commercial frequency and free from interthreaded iron, connected in parallel across alternating current mains, which consists in utilizing the furnace inductor coils as auto transformers to raise the voltage upon the condenser power factor correction and at the same time preventing surging between condensers by including part of the inductor coil in series between each condenser and the power input connection for its furnace inductor and controlling the power input independently to the different inductor coils by varying the number of inductor turns spanned by the power input connections and connecting the lower power input tap above the lower condenser tap.

6. The method of running furnaces in parallel from a constant potential source, which consists in partially correcting the power factor of the individual furnaces, altering the input to the individual furnaces by alteration of voltage across the furnace coils and correcting the out-of-phase component of the supply circuit remaining at the generator mains.

7. The method of controlling and applying to a maximum value high frequency surging from one furnace circuit to another furnace circuit connected in parallel, which consists in providing inductor turns at the bottom of the inductor below the lowest power input connection and in connecting the power fac-

tor corrective capacity in each furnace across to include the turns below this power input connection so that surging shall pass through the lower turns of both furnaces.

8. A polyphase generator, two or more circuits fed therefrom, a plurality of inductor furnace coils in parallel fed from one circuit, a plurality of inductor furnace coils in parallel fed from the other circuits, condenser power factor correction for each of the individual furnace coils connected thereto and spanning different furnace turns from those spanned by the connection with the circuits, and adjustable condenser power factor correction in each circuit correcting the out-of-phase component of the circuit resulting from operation of the furnaces in parallel.

9. An alternating current supply circuit, a plurality of inductor furnace coils free from interthreading with iron connected across the mains in parallel, taps from the inductor coils providing alternative connections for connecting alternating current supply to alter the turns of the inductor coil spanned by the supply and condenser power factor correction for each of the individual inductor coils, spanning different inductor turns of the inductor coil than are spanned by the current supply, the lower condenser being below the lower power input tap.

10. A pair of alternating current mains, adjustable power factor corrective condensers across the mains, a plurality of inductor furnace coils free from interthreading of furnace iron connected across the mains in parallel, approximate individual condenser power factor correction at the furnace coils and inductances between the approximate power factor correction and the connections with the mains.

11. An alternating current source, a plurality of inductor furnace coils connected in parallel across the source, individual partial condenser power factor correction for the separate coils and adjustable additional condenser power factor correction for the source to compensate the out-of-phase component of the current at the source.

12. Two pairs of alternating current mains of different voltages, a pair of inductor coil furnaces, switches for connecting the furnaces in parallel across either pair of mains, coil connections whereby the mains may be made to span different portions of the furnace coil lengths, condenser power factor correction for the individual coils spanning at each furnace a different number of turns of furnace coil than are spanned by the connections to the mains and adjustable condenser power factor correction at the mains for the out-of-phase component of the current drawn from the mains.

13. A plurality of high frequency inductor coil heaters or furnaces, a single high frequency alternator as a source of supply to all the heaters in parallel, taps upon the different heater or furnace coils adapted to be connected with the source of supply to vary the power input to the different furnaces and separate condenser banks across the different coils providing approximate rectification of power factor in the individual coils.

14. A plurality of high frequency heating coils, a single source of current for said coils, power factor corrective means at each of the coils and power factor corrective means common to the different coils.

15. A pair of high frequency pool-surrounding inductor coils, connections for power factor correction across each coil separately, high frequency current supply adapted for connection to each coil separately across a shorter coil length than that spanned by the power factor correction and power factor correction common to both coils, whereby surging of the current in the two coils across from coil to coil is restricted by the additional turns of the inductor coil outside of the portions spanned by the current supply and power factor variation in one coil may be balanced against such power factor variation in the other.

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