

Description

Background of the Invention

This invention relates to switching circuitry for thyristors used in power factor controllers for inductive loads, such as a motor.

U.S. Patents Nos. 4,052,648 (Nola) and 4,266,177 (Nola) disclose power factor controllers particularly useful in connection with induction motors. These controllers, which sample the line voltage and current through the motor, include a thyristor which controls the power input to the motor in proportion to the detected phase difference between the sampled voltage and current, such that less power is provided to the motor in response to decreasing motor loading.

As is well understood in the art, a thyristor, i.e., an SCR or triac, will switch on if its gate electrode is supplied with a current pulse whose duration may be only a few microseconds, and will remain on until the anode current goes to a zero level. If the thyristor is used to control a sinusoidal current in a resistive load, the trigger pulse can be applied during any portion of the sine wave since the current will also be precisely in phase with the voltage. The current in an inductive load significantly lags the voltage, however, and this can create problems in connection with triggering the thyristor. More specifically, if the firing or trigger pulse is generated at a time when current is flowing from the preceding half cycle (due to the current phase lag), the triac will already be turned on at that time. Further, when the current goes to zero and the triac goes off, the triac will remain off for an entire half cycle. The trigger pulse will thus be without effect; the disadvantages of such operation in a thyristor control system are evident.

In a power factor controller of the type discussed above, this problem is avoided by supplying thyristor gate current using a fixed level signal rather than a trigger pulse. However, it will be appreciated that supplying a fixed level signal results in considerably more power consumption than supplying a trigger pulse. Moreover, in certain power factor controllers employing triacs wherein the gate power is derived directly from the line voltage, it has been found necessary to use a sensitive gate pilot triac to turn on the main power triac.

In accordance with this invention, a triggering circuit for a switching device is provided which utilizes a trigger pulse to fire the switching device and which inhibits generation of the trigger pulse if current is flowing from the preceding half cycle. The circuit is particularly adapted for use in power factor controllers because it uses a signal already existing in the controller to inhibit the firing pulse. The trigger circuit of this invention thus eliminates the problems discussed above with reference to pulse firing while also retaining the advantages thereof over fixed level firing and doing away with the need for pilot triacs.

As is known from US-A-4226177, a control system for controlling a switching device provid-

ing an alternating current input to a load which produces a difference in phase signal between the load current and voltage waveforms comprises pulse producing means for producing firing pulses and means for providing a control signal for said pulse producing means based on said phase difference between the load current and voltage. In accordance with the invention means is provided which is responsive to said phase difference signal for inhibiting production of a firing pulse until a time when no current is flowing from the previous half cycle of the alternating current input.

As mentioned the system is particularly useful for use in a power factor controller using a triac to control the load current where the control signal is generated in response to phase difference signals in the controller and in such an application the load can be an induction motor. Preferably, the pulse producing means comprises an electronic switching device such as a transistor, and means which controls the "on" time of the transistor. Advantageously, the inhibiting means establishes a reference point or angle for triggering the triac based on the phase difference signal, and inhibits the production of a firing pulse in advance of the reference point. The base of the control transistor for the triac or thyristor may be connected to receive a first signal from the inhibiting means and a second signal from a control circuit for determining the firing angle of the firing pulses for the thyristor. The thyristor is connected to be turned on only when both the signals are negative. The firing angle of the second signal controls the turn on time of the transistor and thus the thyristor, so long as this firing angle occurs after the reference angle; however, when the firing angle is in advance of the reference angle, the transistor is not turned on until the reference angle is reached.

Figures 1(a) to 1(f) are waveforms associated with conventional thyristors, used in explaining the problem overcome by this invention;

Figure 2 is a schematic circuit diagram, partially in block form, of a power factor controller incorporating the trigger control circuit of this invention; and

Figures 3(a) to 3(m) are waveforms associated with the system of Figure 2 and used in explaining the operation of the trigger circuit thereof.

Figures 1(a) to 1(f) show waveforms associated with conventional thyristor operation. With a thyristor connected to an A.C. input to provide an output current when triggered "on" or fired, and with input current and voltage waveforms as shown in Figure 1(a), if the firing pulses for the thyristor occur at the times shown in Figure 1(b), the output current will be that shown in Figure 1(c). If the firing pulses are advanced in time to coincide with the zero crossing of the current waveform, as indicated in Figure 1(d), continuous current will flow, i.e., the current will be the same as shown in Figure 1(a). If the firing pulses are advanced further in time, however, as indicated in Figure 1(e), such that they occur when current is

still flowing in the previous half cycle (and the thyristor is already "on"), when the current goes to zero the thyristor is turned off and, because the firing pulse has already terminated, the thyristor will remain off for the entire ensuing half cycle as shown in Figure 1(f). It is this problem that the present invention seeks to overcome. Before exploring the invention in more detail, however, a control system in which the invention is incorporated will be described.

Figure 2 shows a preferred embodiment of the invention incorporated in a power factor controller similar to that disclosed in U.S. Patent No. 4,266,177. The system shown in Figure 2 is similar to that described in the patent just referred to and the subject matter of that patent is hereby incorporated by reference.

The system of Figure 2 includes input terminals 10 and 12 which receive the input waveform, typically 115 volts A.C. as shown in Figure 3(a), and which are connected to a power supply circuit 14 and across the series combination of the winding(s) of a motor 16, a thyristor (triac) 18 and a current sensing resistor 20. Input terminal 10 is also connected to positive and negative voltage squaring circuits 24 and 22 which produce respective oppositely phased, full wave, rectangular outputs "f" and "g" shown in Figures 3(f) and 3(g). A signal voltage is developed across current sensing resistor 20 which is shown in Figure 3(b) for a representative mode of operation of triac 16 and in Figure 3(c) for continuous operation (with triac 16 always on), and which is applied to the inputs of full wave current squaring wave shapers 26 and 28. Wave shaper 26 is responsive only to positive half cycles of the current waveform, and in response to the signal shown in Figure 3(b) produces a rectangular output waveform "h" shown in Figure 3(h). Conversely, wave shaper 28 is responsive only to negative half cycles of the current waveform, and produces a rectangular output waveform "i" shown in Figure 3(i).

The outputs "g" and "f" of voltage squaring wave shapers 22 and 24 are connected to a negative going pulse detector 30 which produces negative spikes used in triggering a ramp generator 32 connected to the output of detector 30. The output of ramp generator 32 is connected to the positive (non-inverting) input of an operational amplifier 34 which functions as a zero crossing detector. A control signal to be described below is connected to the negative (inverting) input of operational amplifier 34.

The control signal referred to above is a function of (1) a signal based on the phase difference between the current and voltage applied to motor 16 and (2) a command or reference signal to be described below. The phase difference signal is derived by a selected combination of the outputs of shapers 22, 24, 26 and 28. Specifically, the outputs of shapers 22 and 26 are added in a summing circuit 36 and the outputs of shapers 24 and 28 are added in a summing circuit 38. The signals so produced are rectified by diodes 40, 42

and combined at point 43 to provide the output signal "j" shown in Figure 3(j). The pulses shown in Figure 3(j) are of a constant amplitude and variable width; the width or duration of these pulses is dependent on the phase difference between the input voltage and current.

The pulse signal shown in Figure 3(j) is applied through a resistor 44 to a further operational amplifier 46 and capacitor 48 connected to form an integrator 50.

The command signal referred to above is derived from a potentiometer 52 which is set with motor 16 unloaded and, as explained in U.S. Patent No. 4,266,177 provides a selected power factor or phase angle between current and voltage as determined by the greatest power factor (smallest motor current-voltage phase difference) at which the motor will operate for the loading range to be encountered. The tap of potentiometer 52 is connected to the negative input of amplifier 46 through a resistor 54. The positive input is connected to ground through a resistor 56.

The output of integrator 50 is the control signal referred to above, and is connected to the negative (inverting) input of operational amplifier 34.

The circuitry described thus far is similar to that described in U.S. Patent No. 4,266,177. In accordance with the present invention, a further operational amplifier 58 is provided, the positive (non-inverting) input of which is connected to the summing point 43 and the negative (inverting) input of which is connected to receive a positive bias or reference voltage developed by a voltage divider formed by resistors 60 and 62. The output voltage from amplifier 58 is connected through a resistor 64 to a node 66 connected to the base of a control transistor 68. The output of operational amplifier 34 is connected through a resistor 70 to node 66 and thus to transistor 68. The emitter of transistor 68 is connected through a resistor 72 to the gate electrode of triac 18 while the collector of transistor 68 is connected to an RC timing circuit formed by a resistor 74 and a capacitor 76.

Considering the operation of the system of Figure 2, the phase difference signal at point 43 (shown in Figure 3(j)) is conditioned by being fed to the non-inverting input of amplifier 58. As mentioned above, a positive bias voltage is applied to the inverting input of amplifier 58 through the voltage divider formed by resistors 60 and 62. The resultant output waveform "k" is shown in Figure 3(k). This voltage is summed at node 66 with the output of amplifier 34, the latter being a fixed level firing pulse as shown in Figure 3(e) and being derived from the ramp output "d" (shown in Figure 3(d)) and the control signal output of integrator 50. As will be seen from comparing Figures 3(d) and 3(e), the firing angle θ_F is controlled by the intersection of the ramp "d" and the control signal output of integrator 50. Because the emitter of transistor 68 is essentially at ground potential, transistor 68 will be turned on when the base drive therefor becomes negative. Thus, both input signals "e" and "k" must simul-

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taneously be negative in order to turn transistor 68 on. If both inputs are positive transistor 68 is off, whereas if one is negative and the other positive the two inputs sum to zero as indicated by comparing the waveforms shown in Figures 3(e) and 3(k), and thus transistor 68 is again off (no base current will flow with a zero volt base drive). Thus, the signals "k" and "e" are effectively "ANDed" and transistor 68 will turn on only when both are negative.

When transistor 68 is turned on, triac 18 is also turned on, with gate current flowing from the ground terminal thereof, indicated at 18a, through gate terminal 18b, resistor 72, transistor 68, and the RC network formed by resistor 74 and capacitor 76, to the negative supply. The amount of current flow, which is typically 50 to 100 milliamps, is determined by the value of resistor 72. The length of time this current flows, which is typically 10 microseconds, is determined by the RC time constant. In this regard, a current flow of 100 milliamps for 10 microseconds can be readily supplied by the filter capacitor (not shown) associated with power supply 14. Resistor 74 provides a discharge path for capacitor 76 during each half cycle.

If the firing angle θ_F shown in Figure 3(e) as varied by the power factor controller in response to a varying load, is greater than the reference angle θ_R shown in Figure 3(k), the turn on time of triac 18 will be coincident with the firing angle θ_F . As the load increases on the motor 16, the firing angle or point θ_F will advance in time, i.e., move to the left in Figure 3(e) to increase the on time of transistor 68 until the firing angle θ_F is equal to or greater than reference angle θ_R . This latter situation is illustrated in Figure 3(l) and by firing angle θ_F' and the dashed line waveform in Figure 3(e). Under these circumstances, the base drive for transistor 68 is the signal shown in Figure 3(m). It will be seen that transistor 68 will not turn on at the firing angle θ_F since the base drive voltage is zero at that time, and will remain zero until time θ_R when both signals "l" and "k" are negative and transistor 68 is turned on to fire triac 16.

Claims

1. A control system for controlling a switching device providing an alternating current input to a load which produces a difference in phase signal between the load current and voltage waveforms; said system comprising:

pulse producing means (68, 74, 76) for producing firing pulses, and means (50) for providing a control signal for said pulse producing means based on said phase difference between the load current and voltage; characterized by means (58) responsive to said phase difference signal for inhibiting production of a firing pulse until a time when no current is flowing from the previous half cycle of the alternating current input.

2. A control system as claimed in claim 1, wherein said pulse producing means comprises an electronic switching device (68) and means

(74, 76) for controlling the on time of said electronic switching device.

3. A control system as claimed in claim 1 or 2, wherein said inhibiting means (58) establishes a reference point (OR) in time during a half cycle in advance of which production of a firing pulse is inhibited and at which time a firing pulse is produced.

4. A control system as claimed in claim 1, wherein said pulse producing means comprises a transistor (68) and said inhibiting means (58) ensures that the base drive for said transistor prevents it from being turned on prior to a reference point (OR) in time related to the phase difference between the load current and voltage and provides a pulse for turning on said transistor (68) at said reference point (OR) in time.

5. A control system as claimed in claim 4, wherein the base of said transistor (68) is adapted to receive a first signal from said inhibiting means (58) and a second signal from a control circuit (30, 32, 34) which determines the firing angle of the firing pulse, the arrangement being such that said first and second signals must both be of the same polarity before said transistor is turned on.

6. A control system as claimed in any one of claims 1 to 5, wherein said means (50) for providing a control signal is responsive to phase difference signals provided by means existing in a power factor controller.

7. A control system as claimed in claim 6, wherein said load comprises an induction motor (16) and said control system controls the power supplied to said motor in accordance with the phase difference between motor voltage and current waveforms.

8. A control system as claimed in claim 7 and further comprising means (22, 24) for producing first and second signals proportional to the square wave of the load voltage and the inverse thereof, means (26, 28) for producing third and fourth signals proportional to the square wave of the load current and the inverse thereof, summing means (36, 38) for selectively summing said signals to produce a first square wave having a pulse duration proportional to the phase shift for a positive half cycle of the input current and a second square wave having a pulse duration proportional to the phase shift for a negative half cycle of the input current, said control signal being derived from said square waves.

Patentansprüche

1. Regelsystem zur Regelung einer Schalteinrichtung, welche eine Wechselstromeingangsgröße an eine Last liefert, welche eine Differenz im Phasensignal zwischen der Laststrom- und Spannungswellenform erzeugt, wobei das System eine Impulserzeugungseinrichtung (68, 74, 76) zur Erzeugung von Zündimpulsen und eine Einrichtung (50) aufweist, um ein Steuersignal für die Impulserzeugungseinrichtung zu liefern, basierend auf der Phasendifferenz zwischen dem Laststrom und der Spannung, gekennzeichnet

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taneously be negative in order to turn transistor 68 on. If both inputs are positive transistor 68 is off, whereas if one is negative and the other positive the two inputs sum to zero as indicated by comparing the waveforms shown in Figures 3(e) and 3(k), and thus transistor 68 is again off (no base current will flow with a zero volt base drive). Thus, the signals "k" and "e" are effectively "ANDed" and transistor 68 will turn on only when both are negative.

When transistor 68 is turned on, triac 18 is also turned on, with gate current flowing from the ground terminal thereof, indicated at 18a, through gate terminal 18b, resistor 72, transistor 68, and the RC network formed by resistor 74 and capacitor 76, to the negative supply. The amount of current flow, which is typically 50 to 100 milliamperes, is determined by the value of resistor 72. The length of time this current flows, which is typically 10 microseconds, is determined by the RC time constant. In this regard, a current flow of 100 milliamperes for 10 microseconds can be readily supplied by the filter capacitor (not shown) associated with power supply 14. Resistor 74 provides a discharge path for capacitor 76 during each half cycle.

If the firing angle θ_F shown in Figure 3(e) as varied by the power factor controller in response to a varying load, is greater than the reference angle θ_R shown in Figure 3(k), the turn on time of triac 18 will be coincident with the firing angle θ_F . As the load increases on the motor 16, the firing angle or point θ_F will advance in time, i.e., move to the left in Figure 3(e) to increase the on time of transistor 68 until the firing angle θ_F is equal to or greater than reference angle θ_R . This latter situation is illustrated in Figure 3(1) and by firing angle θ_F' and the dashed line waveform in Figure 3(e). Under these circumstances, the base drive for transistor 68 is the signal shown in Figure 3(m). It will be seen that transistor 68 will not turn on at the firing angle θ_F since the base drive voltage is zero at that time, and will remain zero until time θ_R when both signals "l" and "k" are negative and transistor 68 is turned on to fire triac 16.

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2. A control system as claimed in claim 1, wherein said pulse producing means comprises an electronic switching device (68) and means

(74, 76) for controlling the on time of said electronic switching device.

3. A control system as claimed in claim 1 or 2, wherein said inhibiting means (58) establishes a reference point (OR) in time during a half cycle in advance of which production of a firing pulse is inhibited and at which time a firing pulse is produced.

4. A control system as claimed in claim 1, wherein said pulse producing means comprises a transistor (68) and said inhibiting means (58) ensures that the base drive for said transistor prevents it from being turned on prior to a reference point (OR) in time related to the phase difference between the load current and voltage and provides a pulse for turning on said, transistor (68) at said reference point (OR) in time.

5. A control system as claimed in claim 4, wherein the base of said transistor (68) is adapted to receive a first signal from said inhibiting means (58) and a second signal from a control circuit (30, 32, 34) which determines the firing angle of the firing pulse, the arrangement being such that said first and second signals must both be of the same polarity before said transistor is turned on.

6. A control system as claimed in any one of claims 1 to 5, wherein said means (50) for providing a control signal is responsive to phase difference signals provided by means existing in a power factor controller.

7. A control system as claimed in claim 6, wherein said load comprises an induction motor (16) and said control system controls the power supplied to said motor in accordance with the phase difference between motor voltage and current waveforms.

8. A control system as claimed in claim 7 and further comprising means (22, 24) for producing first and second signals proportional to the square wave of the load voltage and the inverse thereof, means (26, 28) for producing third and fourth signals proportional to the square wave of the load current and the inverse thereof, summing means (36, 38) for selectively summing said signals to produce a first square wave having a pulse duration proportional to the phase shift for a positive half cycle of the input current and a second square wave having a pulse duration proportional to the phase shift for a negative half cycle of the input current, said control signal being derived from said square waves.

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1. Regelsystem zur Regelung einer Schalteinrichtung, welche eine Wechselstromeingangsgröße an eine Last liefert, welche eine Differenz im Phasensignal zwischen der Laststrom- und Spannungswellenform erzeugt, wobei das System eine Impulserzeugungseinrichtung (68, 74, 76) zur Erzeugung von Zündimpulsen und eine Einrichtung (50) aufweist, um ein Steuersignal für die Impulserzeugungseinrichtung zu liefern, basierend auf der Phasendifferenz zwischen dem Laststrom und der Spannung, gekennzeichnet



durch eine Einrichtung (58), welche auf das Phasendifferenzsignal anspricht, um die Erzeugung eines Zündimpulses zu sperren bis zu einem Zeitpunkt, wenn kein Strom vom vorhergehenden Halbzyklus der Wechselstromeingangsgröße fließt.

2. Regelsystem nach Anspruch 1, dadurch gekennzeichnet, daß die Impulserzeugungseinrichtung eine elektronische Schalteinrichtung (68) und eine Einrichtung (74, 76) zur Regelung der Einschalt-Zeit der elektronischen Schalteinrichtung aufweist.

3. Regelsystem nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Sperreinrichtung (58) während eines Halbzyklus einen Referenzpunkt (OR) in Bezug auf die Zeit bildet, wobei vorher die Erzeugung eines Zündimpulses verhindert bzw. gesperrt wird und wobei im Zeitpunkt selbst ein Zündimpuls erzeugt wird.

4. Regelsystem nach Anspruch 1, dadurch gekennzeichnet, daß die Impulserzeugungseinrichtung einen Transistor (68) aufweist und die Sperreinrichtung (58) sicherstellt, daß die Basissteuerung für diesen Transistor diesen daran hindert, vor einem zeitlichen Referenzpunkt (OR) in Bezug auf die Phasendifferenz zwischen dem Laststrom und der Spannung eingeschaltet zu werden, und einen Impuls zur Einschaltung des Transistors (68) in diesem zeitlichen Referenzpunkt (OR) liefert.

5. Regelsystem nach Anspruch 4, dadurch gekennzeichnet, daß die Basis des Transistors (68) ein erstes Signal von der Sperreinrichtung (58) empfangen kann sowie ein zweites Signal von einer Regelschaltung (30, 32, 34), welche den Zündwinkel des Zündimpulses bestimmt, wobei die Anordnung derart ist, daß das erste und zweite Signal die gleiche Polarität aufweisen muß, bevor der Transistor eingeschaltet wird.

6. Regelsystem nach irgendeinem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß die Einrichtung (50) zur Lieferung eines Regelsignals ansprechbar ist auf Phasendifferenzsignale, welche durch Mittel geliefert werden, die in einem Leistungsfaktorregler vorhanden sind.

7. Regelsystem nach Anspruch 6, dadurch gekennzeichnet, daß die Last einen Induktionsmotor (16) aufweist und daß das Regelsystem die Leistung regelt, welche dem Motor in Übereinstimmung mit der Phasendifferenz zwischen der Motorspannung- und Stromwellenform zugeführt wird.

8. Regelsystem nach Anspruch 7, gekennzeichnet außerdem durch eine Einrichtung (22, 24) zur Lieferung erster und zweiter Signale proportional zur Rechteckwelle der Lastspannung und ihrer Invertierung, eine Einrichtung (26, 28) zur Lieferung dritter und vierter Signale proportional zur Rechteckwelle des Laststromes und ihrer Invertierung, eine Summiereinrichtung (36, 38) zum selektiven Summieren der Signale, um eine erste Rechteckwelle zu erzeugen mit einer Impulsdauer proportional zur Phasenverschiebung für eine positive Halbwelle des Eingangsstromes, und um eine zweite Rechteckwelle zu erzeugen, mit einer

Impulsdauer proportional zur Phasenverschiebung für einen negativen Halbzyklus des Eingangsstromes, wobei das Regelsignal von den Rechteckwellen abgeleitet wird.

Revendications

1. Système de commande pour commander un dispositif de connexion alimentant en courant alternatif un récepteur qui engendre une différence de phase entre l'intensité de charge et les ondes de tension, ledit système comprenant des moyens de production d'impulsion (68, 74, 76) pour produire des impulsions d'amorçage et des moyens (50) pour fournir un signal de commande pour lesdits moyens de production d'impulsion dépendant de la différence de phase existant entre l'intensité de charge et la tension, caractérise en ce qu'il comporte des moyens (58) réagissant à ladite différence de phase pour inhiber la production d'une impulsion d'amorçage jusqu'au moment où aucun courant ne provient plus de l'alternance précédente de l'alimentation en courant alternatif.

2. Système de commande selon la revendication 1, caractérisé en ce que lesdits moyens de production d'impulsion comportent un dispositif de commutation électronique (68) et des moyens (74, 76) pour commander l'actionnement dudit dispositif de commutation électronique.

3. Système de commande selon l'une des revendications 1 ou 2, caractérisé en ce que lesdits moyens d'inhibition (58) déterminent un instant de référence (OR) durant une alternance, la production d'une impulsion d'amorçage étant inhibée avant cet instant de référence et ayant lieu à cet instant de référence.

4. Système de commande selon la revendication 1, caractérisé en ce que lesdits moyens de production d'impulsion comportent un transistor (68) et en ce que lesdits moyens d'inhibition (58) garantissent que l'excitation de la base dudit transistor l'empêche d'être mis en circuit avant un instant de référence (OR) rapporté à la différence de phase entre l'intensité de charge et la tension et fournissent une impulsion pour mettre en circuit ledit transistor (68) audit instant de référence (OR).

5. Système de commande selon la revendication 4, caractérisé en ce que la base dudit transistor (68) est approprié à recevoir un premier signal provenant desdits moyens d'inhibition (58) et un second signal provenant d'un circuit de commande (30, 32, 34), lequel détermine l'angle d'amorçage de l'impulsion d'amorçage, la disposition de l'ensemble étant telle que le premier et le second signal doivent être de la même polarité avant que ledit transistor ne soit mis en circuit.

6. Système de commande selon l'une des revendications 1 à 5, caractérisé en ce que lesdits moyens (50) pour fournir un signal de commande réagissent à des signaux de différence de phase fournis par des moyens présents dans un régulateur de facteur de puissance.

7. Système de commande selon la revendica-



tion 6, caractérisé en ce que ledit récepteur comporte un moteur à induction (16) et en ce que ledit système de commande commande la puissance fournie audit moteur en fonction de la différence de phase existant entre la tension du moteur et les ondes de l'intensité.

8. Système de commande selon la revendication 7, caractérisé en ce qu'il comporte en outre des moyens (22, 24) pour produire un premier signal et un second signal proportionnels à l'onde carrée de la tension de charge et à son inverse, les moyens (26, 28) pour produire un troisième et un

quatrième signal proportionnels à l'onde carrée de l'intensité de charge et à son inverse, des moyens d'addition (36, 38) pour additionner sélectivement lesdits signaux afin de produire une première onde carrée ayant une durée d'impulsion proportionnelle au décalage de phase pour une alternance positive du courant d'alimentation et une seconde onde carrée ayant une durée d'impulsion proportionnelle au décalage de phase pour une alternance négative du courant d'alimentation, ledit signal de commande étant dérivé desdites ondes carrées.

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quatrième signal proportionnels à l'onde carrée de l'intensité de charge et à son inverse, des moyens d'addition (36, 38) pour additionner sélectivement lesdits signaux afin de produire une première onde carrée ayant une durée d'impulsion proportionnelle au décalage de phase pour une alternance positive du courant d'alimentation et une seconde onde carrée ayant une durée d'impulsion proportionnelle au décalage de phase pour une alternance négative du courant d'alimentation, ledit signal de commande étant dérivé desdites ondes carrées.

