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Description

The invention relates to an inverter or an output filter for inverters. The output current of an inverter for higher levels of power generally has a whole series of current harmonics. Those harmonics are troublesome and they occur in an unacceptable fashion in particular
5 when a relatively high level of power has to be fed into a network by way of inverters.

Fig. 1 shows an inverter with an output inductor and a capacitor filter network, which inverter significantly reduces the above-described technical disadvantage of inverters and considerably improves the quality of the current. The power switches T1 to T6 and the
10 diodes connected in parallel therewith are switched by means of pulse-width modulation of the power switches in such a way that three sinusoidal output-current phases U, V, W occur at the output of the inverter. The form of the output current is approximated to a sinusoidal oscillation by switching the individual switches T1 to T6 on and off in a defined manner. In that case, however, the above-mentioned harmonics occur due to the inevitable
15 deviations from the reference or target value.

These generated harmonics are in total equal to zero at any moment in the three-phase network. That is the case in any event because there are no other current paths (other electrical circuits). In that situation only symmetrical harmonics occur. The attempt is then
20 made by filter circuits – as also shown at the output side in Fig. 1 – to compensate for those harmonics. As the electrical network, due to the inductive and capacitive sections (components of the transmission line) also has in part very low impedances (resistances) for certain frequencies, undesirably high proportions of the harmonics still flow into the public supply network.

25 An inverter-fed motor drive, with an absorption circuit arrangement on the output side for reducing electromagnetic interference which arises, is known from the document 5,661,390 A.

30 A further inverter-fed motor drive, in which conducted interference emissions are suppressed, is known from the document EP 0 758 161 A2.

An active common mode canceler, which eliminates disturbances caused by stepwise changes in a common mode voltage generated at the time of switching of a power
35 semiconductor device of a power converter, is known from the document US 5,831,842 A.

Therefore the object of the invention is to eliminate the disadvantages mentioned in the prior art, so that only current with very low harmonics and if possible no harmonics at

all is still fed into the public supply network. In addition, the d.c. voltage intermediate circuit of the inverter should be stabilized in respect of electrical potential (voltage value in relation to the housing, earth or the three-phase system).

5 In accordance with the invention, in order to attain the object set, an inverter is proposed having the features according to Claim 1. Advantageous further developments are set out in the Sub-Claims.

10 With the inverter according to the invention, asymmetrical harmonics are generated at the inverter output side and are fed back into the d.c. intermediate circuit. To produce the asymmetrical harmonics, in addition to the three-phase output inductor present at the inverter output, there is a further winding (fourth leg). This further winding transmits asymmetrical magnetic fluxes which arise out of the asymmetrical harmonics. The harmonics are collected by way of three resonant circuits, for example three LC members.
15 If there are still any symmetrical harmonics present at all, they are directly compensated with the said resonant circuits. The asymmetrical harmonics ($\Sigma i \neq 0$) are fed back to the d.c. voltage intermediate circuit. The sum of the asymmetrical harmonics is taken off at the star point of the resonant circuits (of the filter capacitors of the resonant circuits) and is coupled in or passed by way of a winding on the fourth leg into the negative bar of the d.c.
20 voltage intermediate circuit. This results in a closed "harmonic current circuit" which is illustrated diagrammatically in Fig. 2.

The total current of the asymmetrical harmonics, which is taken off at the star point of the resonant circuits, produces magnetic fluxes in the fourth leg of the output inductor.
25 Depending upon the current situation, those magnetic fluxes flow back into the three main legs of the output inductor and thus support the output inductance. As a result, there is an output inductance which is approximately from 5% to 20% higher than in a conventional three-phase inductor. As only the harmonic current flows in the fourth winding, only very low levels of copper losses occur in this case – in relation to the main coils of the inductor.
30

The invention and advantageous further developments as well as the advantages thereof are explained by way of example in the following description to the drawing. In the drawing

Fig. 1 is a schematic circuit diagram of a known inverter;

35 Fig. 2 is a schematic circuit diagram of an inverter according to the invention;

Fig. 3 is a measuring diagram of an inverter according to the invention;

Fig. 4 is a cut-away view from Fig. 3 with increased resolution;

- Fig. 5 is a measuring diagram of an inverter according to the invention;
 Fig. 6 is a measuring diagram of an inverter according to the invention;
 Fig. 7 is a circuit diagram of a preferred embodiment of an inverter according to the invention, and
 5 Fig. 8 is a current-measuring diagram for the inverter and network current.

Fig. 1 is the circuit diagram of a known inverter which by virtue of the anti-parallel connexion of the power switches T1 to T6 with a respective diode D1 to D6 permits a four-quadrant mode of operation and can thus be put to very versatile use as a circuit. To
 10 produce the positive half-wave of the output current, the known inverter involves implementing successive switching-on and switching-off of the switches T_n ($n = 1, 3, 5$) and T_{n+1} ($n = 2, 4, 6$). For a half-wave of the output current of the U phase of the three-phase current, this means that T1 and T6 are successively switched on and off a number of
 15 times during a half-wave. Connected upstream of the power switches is a d.c. voltage intermediate circuit with two series-connected electrolytic capacitors C4 and C5 for feeding in the d.c. voltage $+U_d$ and $-U_d$. On the output side the inverter has an output inductor LA (LAU, LAV, LAW) and a filter connected downstream and comprising three
 20 capacitors C6, C7, C8 which are arranged between the respective phases. As already described, the form of the three-phase output current U, V, W is approximated to a sinusoidal oscillation by the individual power switches T1 to T6 being switched on and off in a defined manner. In that case, however, harmonics occur due to the inevitable
 25 deviations from the reference or target value. The said generated harmonics are equal to or almost zero in total at any time in the three-phase network. That is the case because there are no other current paths. The harmonics which occur, however, are always symmetrical and the attempt is made by means of the capacitor filter circuit to compensate for the said
 30 harmonics. As, however, the electrical network, due to the inductive and capacitive sections (components of the transmission line) also has in part for certain frequencies very low impedance levels (resistances), high proportions of the harmonics still flow into the public supply network, which is highly undesirable.

Fig. 2 shows the circuit diagram of an inverter according to the invention. Like the known inverter, it has a d.c. voltage intermediate circuit, power switches T1 to T6 and diodes D1 to D6 connected in parallel therewith, and an output inductor LA.

35 The inverter according to the invention produces asymmetrical harmonics. For that purpose an additional winding L4 (additional leg) is provided. The said fourth leg L4 transmits the asymmetrical magnetic fluxes which arise out of the asymmetrical harmonics.

The harmonics are [collected]¹ by way of three resonant circuits LC or three L-C members, comprising the inductances L1 to L3 and the capacitors C1 to C3, and a common star point. If there are still any symmetrical harmonics present at all, they are directly compensated with the said resonant circuits LC. Asymmetrical harmonics L4 ($\Sigma I \neq 0$) are
5 passed by way of the star point to the winding of the fourth leg L4. The said fourth winding L4 is connected to the negative bar of the d.c. voltage intermediate circuit. The sum of the asymmetrical harmonics is thus taken off at the star point of the filter capacitors and is coupled into the d.c. voltage intermediate circuit by way of the winding on the fourth leg L4. That gives a closed harmonic circuit for the asymmetrical harmonics.

10 The total current of the asymmetrical harmonics, which is taken off at the star point of the capacitors, produces magnetic fluxes at the fourth leg of the output inductor LA. Depending upon the respective situation, the said magnetic fluxes flow back into the main legs of the output inductor LA, which are magnetically coupled to the fourth leg, and assist
15 the output inductance thereof.

As a result thereof, this gives an output inductance LA which is approximately from 5 to 20% higher than in a conventional three-phase inductor. As only the harmonic current of the asymmetrical harmonics flows in the fourth winding LA4, in this case only very low
20 levels of copper losses occur, in comparison with those in the main coils LA1, LA2, LA3.

Fig. 3 is a measuring diagram of the inverter shown in Fig. 2. The upper curve shows the positive sinusoidal half-oscillation of the current at the inverter output. In this case the hysteresis of the current is constant and the switching frequency is variable. The lower
25 curve shows the sum of the harmonics of the three output phases of the inverter, which flow back into the d.c. voltage intermediate circuit by way of the fourth leg.

Fig. 4 shows once again a part of the output current of the inverter of phase 1 in a higher degree of resolution. In this case, the triangular harmonics of the output current
30 IWR LA can be clearly seen.

The said harmonics are separated at the output of the output inductance LA from the (sinusoidal) fundamental component of the output current with the resonant circuit comprising L1 and C1. The lower curve in Fig. 4 shows the pattern in respect of time of
35 the current IL1C1 in L1 and C1.

¹ N.B. The passive participle is missing in the original German text, *i.e.* the word “collected” has been supplied solely to make the sentence grammatical.

Fig. 5 shows the result of separation of the harmonics from the main current (fundamental component 50 Hz). The uppermost curve shows the output current without harmonics. This very good result is possible only with the harmonic circuit according to the invention. In this case, as can be seen from the Figures, the harmonics produced are fed back by almost 100% from the inverter into the d.c. voltage intermediate circuit. The middle curve in Fig. 5 shows the inverter current IWR LA and the lower curve in Fig. 5 once again shows the associated harmonic current.

Fig. 6 (lower curve) shows the sum of the three harmonic currents I21, I22 and I23. This current which contains almost all harmonics of the three phases is now used once again to enhance the action of the output inductor LA.

As already described, the said inductor comprises the three main legs LA1, LA2, LA3 for the three main output windings and a fourth small subsidiary leg which is provided only for the harmonics. The said fourth leg carries only the magnetic fluxes which correspond to the sum of the harmonics. The corresponding amplitude of the said summation current of the harmonics is shown in Fig. 6, lower curve. The upper curve shows the corresponding voltage configuration. In order to achieve this, an iron cross-section of approximately 20% of the main legs is sufficient for the fourth leg. The fourth leg, however, increases the effective output inductance LA by approximately from 5 to 20%. This results in the output inductor LA being smaller in size, and a better level of efficiency.

Fig. 7 shows a further development of the inverter according to the invention. In this case the output inductor is constructed in two parts and comprises a four-leg inductor and a compensated three-phase inductor LA2 which is connected in series therewith. Current-compensated inductors can advantageously be used for asymmetrical harmonic currents. As the sum of the network current (three-phase current) is equal to zero, the inductor is not loaded with the very high fundamental components (pre-magnetized). In this way, a high level of inductance can be built up with little outlay.

Fig. 8, upper curve, shows the sum of the three output currents at the inverter output upstream of the filter. In this case the maximum amplitude is only 10% of the peak value of a phase current. The lower curve shows the sum of the output currents downstream of the filter. It will be seen that this output current is of extremely high quality and does not couple any negative harmonics into the network.

The d.c. voltage intermediate circuit is also simultaneously stabilized with the closed harmonic circuit. The star point of the three capacitors has a stationary potential, and in

principle the same potential as earth. As this point is statically connected by way of the inductance to the intermediate circuit, a compensating current flows by way thereof if the potential of the intermediate circuit changes. Abruptly changing potentials are harmful to generators which feed into the d.c. voltage intermediate circuit as due to changes in the voltage (dU/dt) a capacitive current would flow through the insulation and in the long term causes insulation damage.

An inverter according to the invention is preferably used in a system for generating electrical energy, for example a wind-power installation. Such electrical energy-generating systems then supply the network with a current of the highest quality, which also has the consequence that that the respective network operator has to implement fewer measures for safeguarding the quality of the current.

P a t e n t k r a v

1. Vekselretter til frembringelse af en veksel- eller trefasestrøm fra en jævnspænding med

- 5 - en jævnspændingsmellemkreds og
 - på udgangssiden en udgangsdrossel (LA),

kendetegnet ved

- 10 - tre svingningskredse (LC), bestående af induktionerne L1 til L3 og kondensatorerne C1 til C3 og et fælles stjernepunkt for at kompensere for symmetriske oversvingninger, der forekommer på udgangssiden;
 - en yderligere vikling, som via en direkte ledning er forbundet mellem stjernepunktet og jævnspændingsmellemkredsen for at koble usymmetriske oversvingninger, der forekommer på udgangssiden, ind i jævnspændingsmellemkredsen.

15

2. Vekselretter ifølge krav 1,

kendetegnet ved, at der med vekselretteren afgives en veksel- eller trefasestrøm via M-ledninger, hvor M-ledningerne er forbundet med hinanden via svingningskredsene.

20

3. Vekselretter ifølge krav 1,

kendetegnet ved, at udgangsdrosslen overfører usymmetriske magnetstrømme, som opstår af de usymmetriske oversvingninger.

25

4. Vekselretter ifølge krav 3,

kendetegnet ved, at udgangsdrosslen består af $m + 1$ ben, hvor m er et naturligt tal, hvor der til hver trefasestrøm-fase er tilknyttet et ben, og de usymmetriske magnetstrømme, som opstår af de usymmetriske oversvingninger, overføres ved hjælp af det $m + 1$ første ben.

30

5. Vekselretter ifølge et af de foregående krav,

kendetegnet ved, at $m + 1$ benene er magnetisk koblet med hinanden, og magnetiske strømme, som forekommer i $m + 1$ benet, strømmer tilbage til m benene af udgangsdrosslen.

35

6. Vekselretter ifølge et af de foregående krav,
kendetegnet ved, at $m + 1$ benet kun gennemstrømmes af en oversvingningsstrøm.
- 5 7. Vekselretter ifølge et af de foregående krav,
kendetegnet ved, at udgangsdroslen er en strømkomenseret drossel.
8. Vekselretter ifølge et af de foregående krav, hvor udgangsdroslen består af en firbenet drossel og en seriekoblet trefasedrossel.
- 10 9. Vekselretter ifølge et af de foregående krav,
kendetegnet ved, at jævnspændingsmellemkredsen stabiliseres med den lukkede oversvingningskreds.
- 15 10. System, der fremstiller elektrisk energi, nemlig et vindenergianlæg med en vekselretter til frembringelse af veksel- eller trefasestrøm ifølge et af de foregående krav.

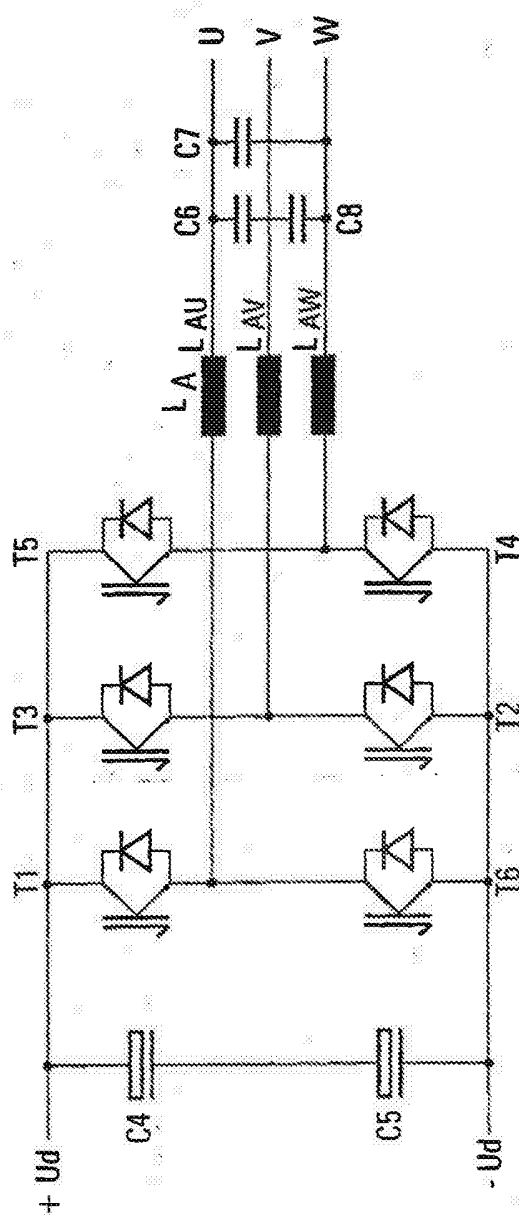


Fig. 1

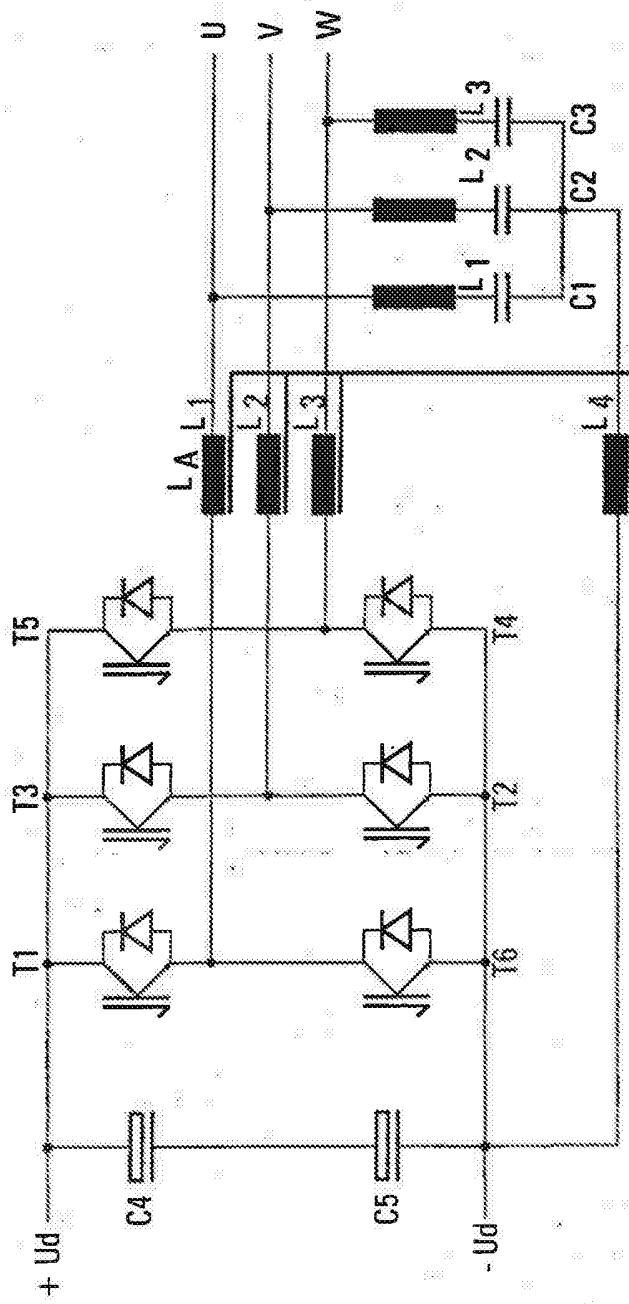


Fig. 2

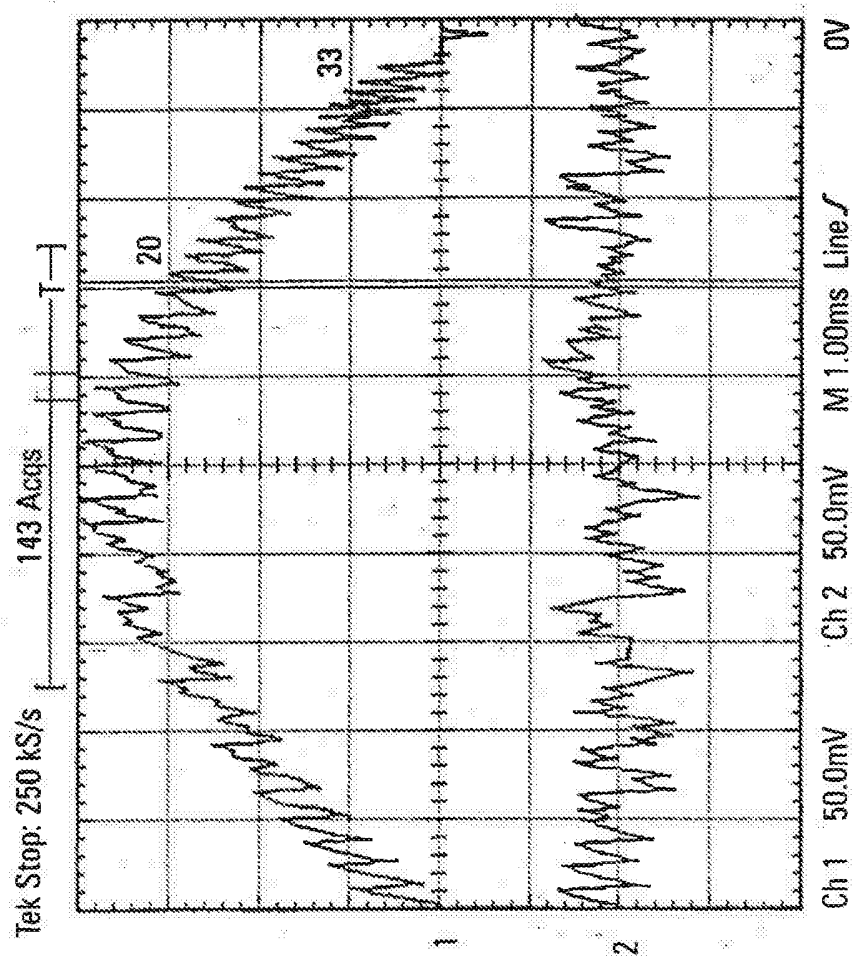


Fig. 3

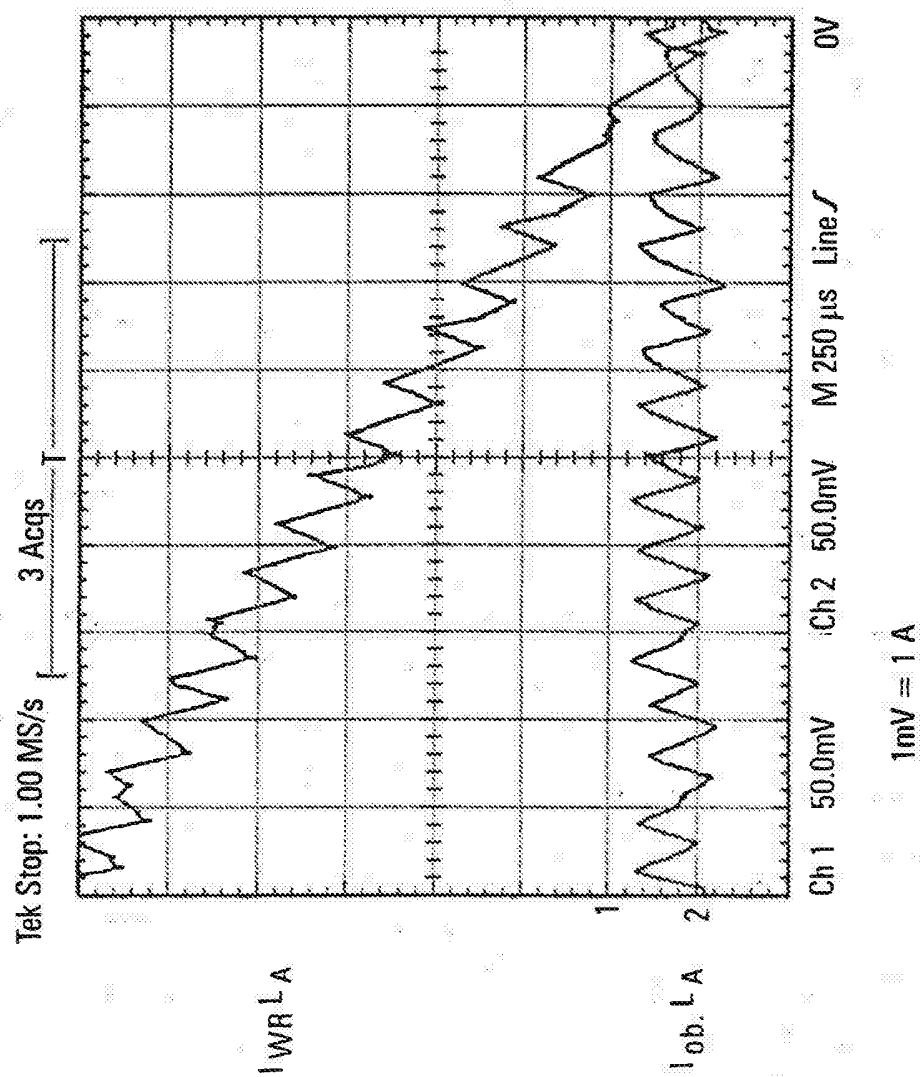


Fig. 4

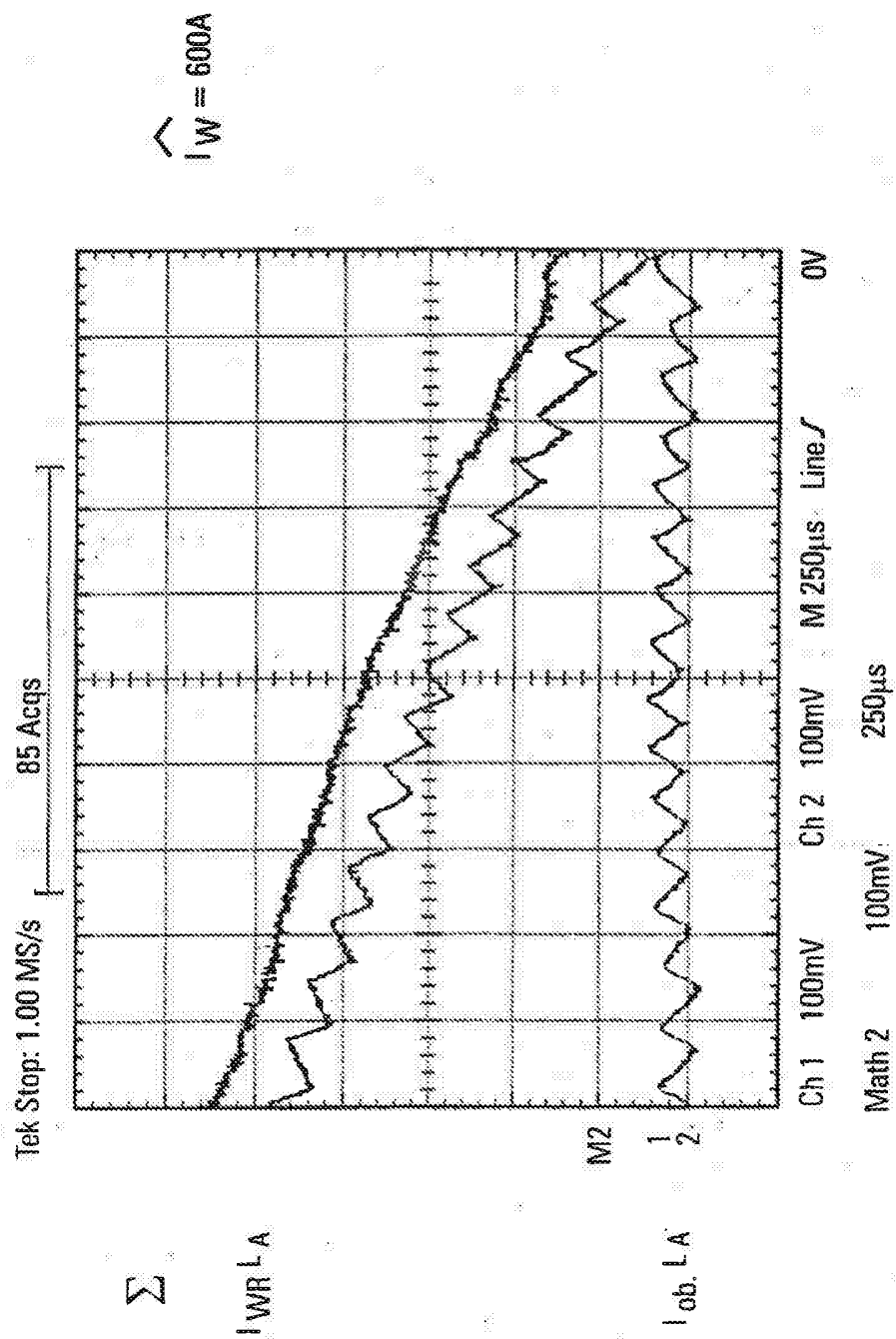


Fig. 5

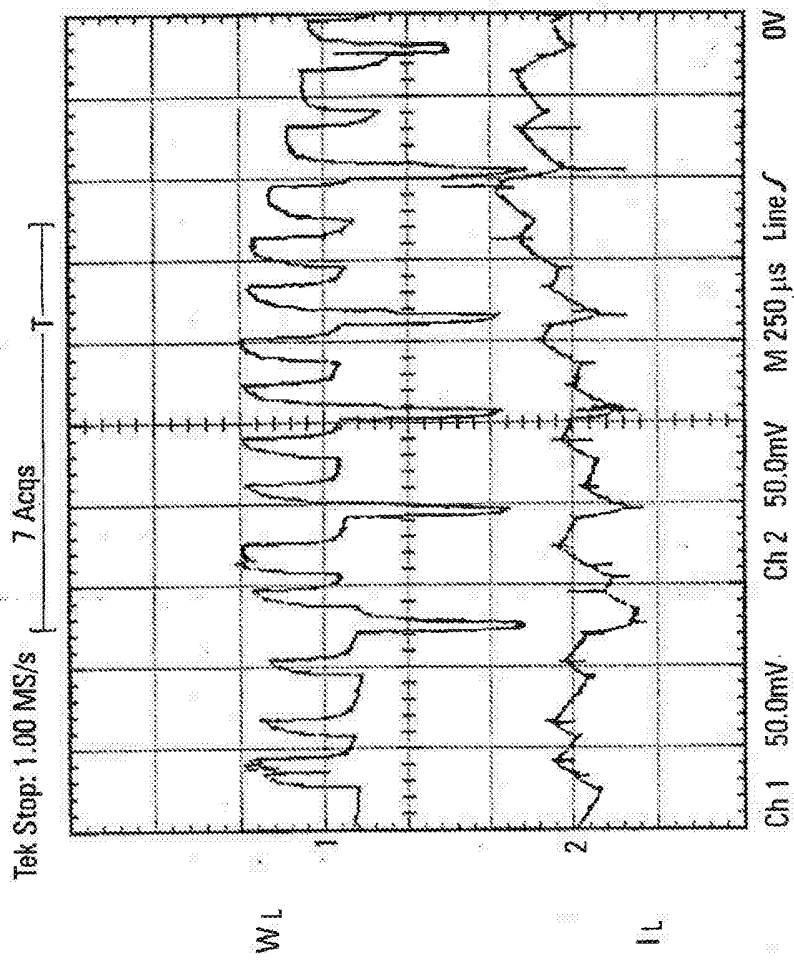


Fig. 6

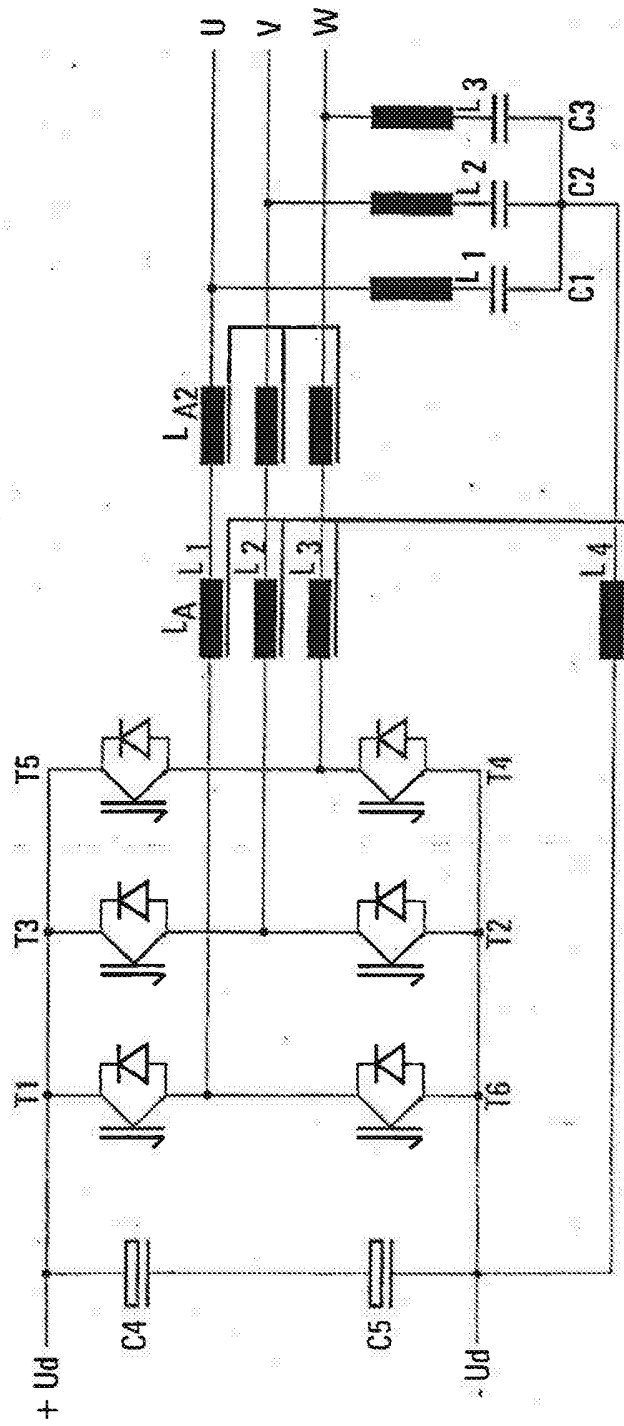


Fig. 7

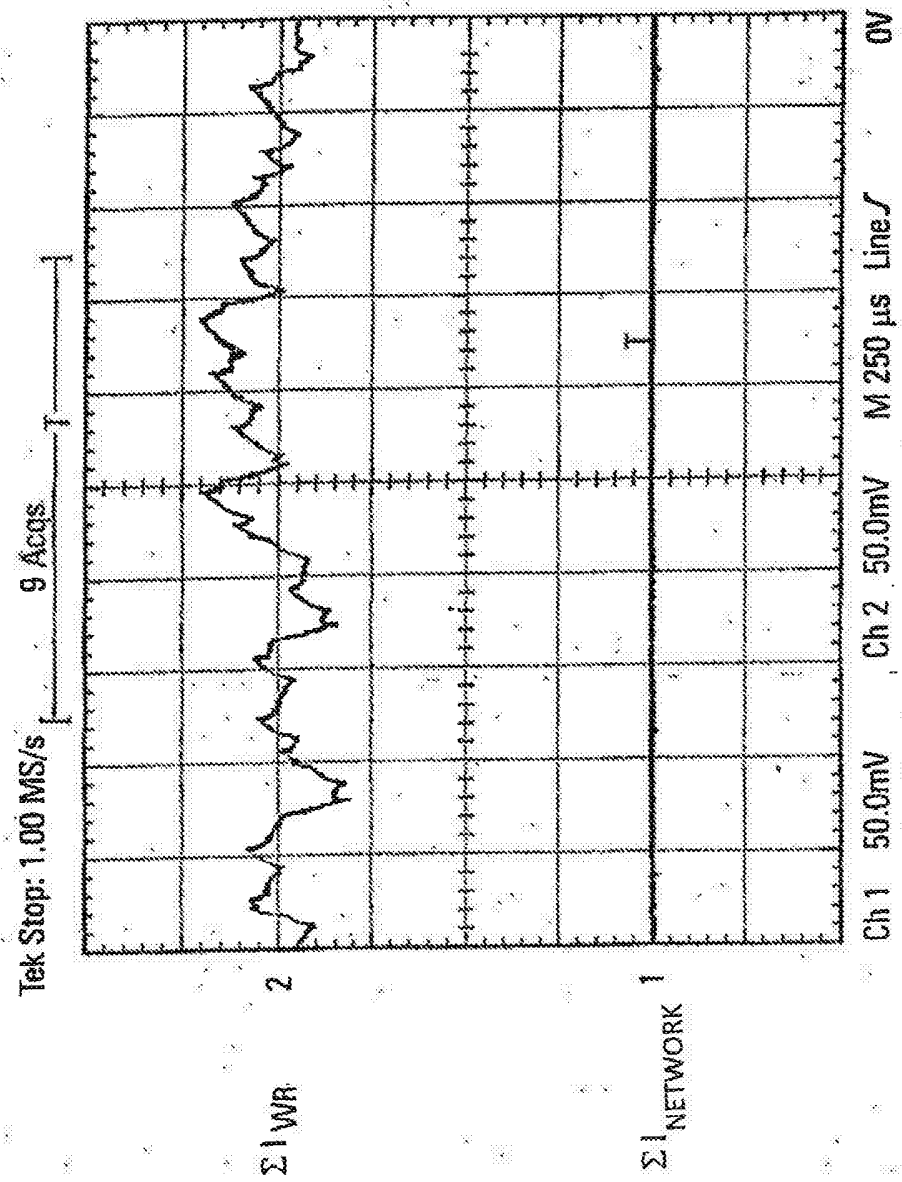


Fig. 8