

Description

This invention relates to pulse-width-modulated (PWM) inverters and converters and particularly to the effect of blanking time interval on output voltage of those inverters and converters.

In PWM inverters and converters, the phase voltage is composed of a series of square pulses of short duration compared to the fundamental frequency. These pulses are of constant magnitude and variable pulse widths.

The output voltage waveform of an inverter is a pulse train whose polarity reverses periodically to provide the fundamental frequency. The repetition rate of the output pulse train is the carrier frequency f_c , if a triangle comparison PWM method is used. Variation of the width of the pulses that make up each half period controls the RMS voltage magnitude. This variation or modulation is achieved in practice by many techniques. A common technique is known as the triangulation or subharmonic method in which the duration of pulses that control switches in power circuit is determined by the crossover points of two reference signals: a high-frequency triangular voltage wave and a sinusoidal voltage varying at fundamental frequency. The PWM signal is used to control the switches in a bridge at f_c .

Ideally, the transistors in each leg of the bridge circuit instantaneously turn off when the PWM signal changes to its inactive state, for example, changes from logic 1 to logic 0. However, in practical circuits utilizing transistor-type circuits, instantaneous turn-off of the transistors is not realizable. For example, when a PWM signal supplied to a pair of switches in a bridge leg changes from logic 1 to logic 0, the first transistor does not turn fully off before the second turns on. This is because a finite amount of time is required for a transistor to come out of saturation after the PWM drive signal changes to its inactive state (logic 0). This results in simultaneous conduction of the two transistors in the bridge leg. Since the two transistors form a series connection across the power supply, their simultaneous conduction results in excessive current and the destruction of the transistors. To avoid this problem, an intentional blanking interval is introduced into the PWM signal driving the bridge circuit. In other words, the turn-on of the second switch in the inverter leg is delayed by a blanking time t_A , to avoid a short circuit through the inverter leg. The duration of the time delay t_A is sufficient to ensure that both transistors in the inverter leg are off before allowing a transistor in the pair in the bridge circuit to turn on. The blanking interval time is also known as the dead time.

Since both the switches are off during the blanking time, the line-to-neutral voltage during that time interval depends on the direction of the load current. When a load current i_A is positive (going from inverter

to load), this results in a voltage loss $\Delta U_A = U_{DC} * [t_A/T_C]$ and when the current is negative, in a voltage gain $\Delta U_A = U_{DC} * [-t_A/T_C]$, where t_A is equal to the blanking time interval, T_C is equal to the period of the carrier frequency and U_d is the DC bus voltage. It is desirable to minimize ΔU_A .

Assuming a three-phase, three-legged power conversion bridge (converter or inverter), the same analysis applies to the second leg B and third leg C. The distortion in U_A , U_B , and U_C at zero crossings of phase currents in i_A , i_B , and i_C results in harmonics, such as third, fifth, seventh, and so on of the fundamental frequency in the inverter or converter output.

The need for compensation of a blanking time interval is well known (see European Patent Publication EP-A-171415 of Goff et al, entitled

"Current Sense Demodulator"); as are the problems with harmonics caused by the blanking interval which have also long been recognized (Ned Mohan, Tore M. Underland, William P. Robbins, "Power Electronics Converters, Applications, and Design", John Wiley & Sons, New York, 1989, pp 141-144).

One method of compensating for blanking interval loss is disclosed in European Patent Publication EP-A-85541 of Sakamoto et al.

which relies upon voltage feedback. This arrangement employs a voltage converting circuit for generating an impressed voltage from an armature voltage U_C , a subtracting circuit for calculating the difference between the output voltage of a holding circuit and the output voltage of the voltage converting circuit, and an integrating circuit for integrating the difference generated by the subtracting circuit. In other words, the output voltage of the inverter circuit is fed back to a pre-stage of the PWM circuit to raise the gain using the feedback loop. However, with an arrangement in which a microprocessor is used as a portion of the motor control circuit, it is necessary to provide separate analog circuits for these feedback loops. This process must be implemented by fast analog circuits and cannot be performed quickly enough by the microprocessor. The solution is complicated in construction and carried out at high cost.

A second apparatus for compensating for PWM blanking time is disclosed in European Patent Publication EP-A-121575 of Kurakake et al. Kurakake discloses a motor control apparatus including an arithmetic circuit for calculating the current command, a holding circuit for holding the current command, a PWM circuit for pulse-width-modulating an output signal from the holding circuit and provided with a dead zone with respect to the output signal, and a transistorized amplifier circuit for controlling a motor by a PWM signal. The arithmetic circuit adds a compensating signal to the current command to compensate for motor control losses due to the blanking time and delivers the result to the holding circuit. This discloses a solution to the problem of losses and distortion

tion that result from the blanking time, but creates another problem in that the compensation is performed all the time. For example, when the PWM circuit is commanded to be near saturation (full conduction of the complementary switches in a power circuit), an additional compensating signal may bring the PWM circuit into saturation and provide excessive load voltage. On the other hand, when the PWM circuit is commanded to go into saturation by the reference voltage, a blanking interval voltage deviation signal can bring it out of saturation, thereby unintentionally reducing the load voltage. In sum, compensation performed all the time causes additional load current distortion when the PWM circuit operates near saturation.

According to one aspect of the present invention there is provided a method for compensating a voltage deviation in the output voltage of a pulse-width-modulation voltage inverter or converter, said inverter or converter including a bridge having at least three legs, said PWM using a carrier signal, the magnitude of the carrier signal having a positive peak and negative peak, comprising the steps of:

providing a plurality of reference current signals, each displaced by a phase angle from the adjacent reference current, one reference current associated with each leg;

providing a plurality of first augmented reference voltage signals, each first augmented reference voltage being associated with a single one of said reference current signals;

calculating a blanking interval compensation voltage signal in response to a DC bus voltage of said inverter or converter, a blanking interval, and a period of said carrier signal; characterised by

adding the blanking interval compensation voltage signal to each of said first augmented reference voltage signals when said inverter or converter is not saturated and said step of adding will not cause said inverter or converter to saturate, thereby providing a plurality of second augmented reference signals; and

providing said second augmented reference signals to a pulse-width modulation circuit.

According to a preferred embodiment, there is provided a method for compensating a voltage deviation in the output voltage of a pulse-width-modulation (PWM) inverter or converter, said inverter or converter including a bridge having at least three legs, said PWM using a carrier signal, the magnitude of the carrier signal having a positive peak and a negative peak, comprising the steps of:

providing a plurality of reference current signals, each displaced by a phase angle from an adjacent reference current, one reference current associated with each leg;

providing a plurality of first augmented reference voltage signals to a pulse-width modulation circuit, each first augmented reference voltage being as-

sociated with a single one of said reference current signals;

calculating a blanking interval compensation voltage signal in response to a DC bus voltage of said inverter, or converter, a blanking interval, and a period of said carrier signal;

providing the product of said blanking interval compensation voltage signal and the polarity of the magnitude of one of said reference currents;

summing said product with said one of said first augmented reference voltage signal and providing a sum;

providing a second augmented reference voltage signal, including the steps

comparing said positive peak to said first augmented reference voltage signal and providing said second augmented reference voltage signal at a value equal to the positive peak when said first augmented reference voltage signal is greater than said positive peak;

comparing said negative peak to said first augmented reference voltage signal and providing said second augmented reference voltage signal at a value equal to the negative peak when said first augmented reference voltage signal is less than said negative peak;

comparing said sum with said positive peak and providing said second augmented reference voltage signal at a value equal to the magnitude of said first augmented reference voltage signal when said positive peak is less than said sum;

comparing said sum with said negative peak and providing said second augmented reference voltage signal at a value equal to the magnitude of said first augmented reference voltage signal when said negative peak is less than said sum;

providing said second augmented reference voltage signal at a value equal to said sum if said sum is neither greater than nor less than said positive and negative peaks.

According to a third aspect there is provided a device for compensating a voltage deviation in the output voltage of a pulse-width-modulation inverter or converter, said inverter or converter including a bridge having at least three legs, said PWM using a carrier signal, the magnitude of the carrier signal having a positive peak and a negative peak, comprising:

means for providing a plurality of reference current signals, each displaced by a phase angle from the adjacent reference current, one reference current associated with each leg;

means for providing a plurality of first augmented reference voltage signals, each first augmented reference voltage being associated with a single one of said reference current signals;

means for calculating a blanking interval compensation voltage signal in response to a DC bus voltage of said inverter or converter, a blanking interval

and a period of said carrier signal;

means for providing the product of said blanking interval voltage deviation compensation signal and the polarity of the magnitude of one of said reference currents;

means for summing said product with said one of said first augmented reference voltage signal and providing a sum;

means for providing a plurality of second augmented reference voltage signals to a pulse width modulation circuit, characterised by

first means for comparing said positive peak to each of said first augmented reference voltage signals and providing said second augmented reference voltage signals at a value equal to the positive peak when said first augmented reference voltage signal is greater than said positive peak;

second means for comparing said negative peak to said first augmented reference voltage signal and providing said second augmented reference voltage signal at a value equal to the negative peak when said first augmented reference voltage signal is less than said negative peak;

third means for comparing said sum with said positive peak and providing a second augmented reference voltage signal at a value equal to the magnitude of said first augmented reference voltage signal when said positive peak is less than said sum;

fourth means for comparing said sum with said negative peak and providing said second augmented reference voltage signal at a value equal to the magnitude of said first augmented reference voltage signal when said negative peak is less than said sum;

means for providing said second augmented reference voltage signal at a value equal to said sum if said sum is neither greater than nor less than said positive and negative peaks.

For a three-phase power conversion bridge, when one of the three reference voltages is greater than the other two, a switch in one of the three complementary pairs of switches in the bridge conducts, while in each of the other two complementary pairs both switches open and close in response to the PWM signal such that only two currents are independently controlled by each of the two complementary pairs which are allowed to open and close, and the third current, associated with the complementary pair which is not allowed to switch, is controlled by the other two. Keeping one switch in each leg closed for one-third of the period of the reference voltage allows control of all three load currents to be dictated by the switching in only two legs of the bridge. The inclusion of step (e) provides that voltage deviations caused by the use of a blanking interval are minimized for the two legs that are not in continuous conduction. For an inverter, the deviations are in the locally averaged AC output voltage. For a converter, the deviations are in the locally averaged AC input voltage.

The first object of the invention is to compensate for a PWM inverter output voltage deviation caused by a blanking interval by adding a voltage, equal to the deviation but with the opposite polarity, to the PWM input.

A second object is to compensate for a PWM inverter output voltage deviation caused by a blanking interval by adding a voltage, equal to the deviation but with the opposite polarity, to the PWM input but only when the PWM circuit is not saturated and the addition would not saturate the PWM circuit.

The third object is to compensate for a PWM inverter output voltage deviation caused by a blanking interval by adding a voltage, equal to the deviation, to the PWM input but only when the PWM circuit is not saturated and the addition would not saturate the PWM circuit, where each leg of the PWM inverter takes a turn at being in continuous conduction for one third of the switching cycle of the input reference voltage.

A preferred embodiment of the present invention will now be described by way of example only and with reference to the accompanying drawings wherein

Fig. 1 shows a block diagram for implementing the present invention in an inverter;

Fig. 2 is a voltage v. time graph of a three-phase sinusoidal voltage, U_{ABC} wherein the amplitude modulation index $m_A < 1$;

Fig. 3 is a voltage v. time graph of a difference signal, U_{DD} . Figs. 2 and 3 are on a common time line and $m_A < 1$;

Fig. 4 shows a blanking interval voltage deviation compensation logic routine for compensating that loss; and

Fig. 5 shows a circuit for implementing the invention in a converter.

Fig. 1 shows a block diagram for implementing the invention in an inverter. It consists of a reference modification block (RMB) 1, a PWM block 3, and a semiconductor bridge 5. The bridge 5 may be for inversion (Fig. 1), DC to AC, or conversion (Fig. 5), AC to DC. For an inverter, the invention compensates voltage deviation in the inverter output. For a converter, the invention compensates voltage deviation in the AC converter input. PWM 3 and bridge 5 together comprise a power conversion circuit 7. RMB 1 is responsive on lines 2, 4, 6 to three sinusoidal reference voltages U_A , U_B , U_C , a triangle voltage U_T , and produces three first augmented reference voltages (U_A' and U_B' and U_C') on lines 40, 38, 36. U_A and U_B and U_C are command reference signals; DC power is obtained from two DC voltage sources $U_{DC}/2$. The three reference voltages (U_A and U_B and U_C) are spaced 120° apart from one another. The first augmented reference voltages (U_A' and U_B' and U_C') are 120° apart. RMB 1 consists of three summers 8, 10, and 12, a reference voltage comparator 20, and fourth summer 24 responsive to the magnitude of a triangle peak U_{TP} of

the carrier signal U_T . The magnitude of the carrier signal has a positive peak U_{TP} , and a negative peak $-U_{TP}$. The three reference voltages (U_A and U_B and U_C) are provided on lines 2, 4, 6 to RMB 1 and to summers 8, 10, 12. In a reference voltage comparator 20, the magnitudes of each voltage (U_A and U_B and U_C) are compared and the greatest, U_{MAX} , is produced on a line 22 to a summer 24. The reference voltage comparator 20 compares two of the reference voltages and then compares the greater of these two to a third reference voltage to provide U_{MAX} .

In Fig. 1, a constant voltage triangle peak value U_{TP} of triangle signal U_T is produced in the PWM 3 and provided on line 29 to the summer 24. In the summer 24, the greatest voltage, U_{MAX} , is subtracted from the triangle peak signal U_{TP} on line 29, and the difference U_{DD} provided on lines 34, 32, 30 to summers 8, 10, 12. At the summers 8, 10, 12, the difference signal U_{DD} is added to each of the reference voltage signals (U_A and U_B and U_C), thus providing first augmented reference voltage signals (U_A' and U_B' and U_C') which are supplied to a blanking interval voltage deviation compensator 102 over lines 40, 38, and 36. In Fig. 1, a PWM 3 contains three summers 42, 44, 46, three comparators 48, 50, 52, and a triangle signal generator 54. Each of the summers 42, 44, and 46 is responsive to second augmented reference voltage signals (U_A'' and U_B'' and U_C'') on lines 116, 114, 112 and the triangle signal U_T provided by the triangle signal generator 54 onto lines 47, 49, 51. The triangle signal generator 54 also provides $+U_{TP}$ on line 29. The triangle signal U_T has peaks of $+U_{TP}$ and $-U_{TP}$. The summers 42, 44, 46 provide error signals (E_A and E_B and E_C) to the comparators 48, 50, 52. If E_A , E_B or E_C is greater than zero (i.e., U_X is greater than U_T), the output of the associated comparator 48, 50, or 52 assumes a value $U_{SX}'' = 1$, where X is A, B, and C for comparators 48, 50, 52. Thus, the comparators 48, 50, 52 produce switch signals (U_{SA}'' and U_{SB}'' and U_{SC}'') on lines 53, 55, 57 and provide them to the bridge 5. The bridge 5 includes three legs 56, 58, 60.

In Fig. 1, each leg includes two complementary semiconductor switch assemblies. The first leg includes a switch S1, a freewheeling diode D1 shunting that switch, and a complementary switching assembly—a NOT gate 62, a switch S1*, and a freewheeling diode D1* shunting that switch. The second leg 58 includes a switch S2, a freewheeling diode D2 shunting that switch, and a complementary switching assembly—a switch S2*, a NOT gate 64, and a freewheeling diode D2* shunting that switch. The third leg 60 includes a switch S3, a freewheeling diode D3 shunting that switch, and a complementary switching assembly—a switch S3*, a NOT gate 66, and a freewheeling diode D3* shunting that switch.

The first, second, and third legs 56, 58, 60 of the bridge 5 are responsive to the switch signals (U_{SA}'' and U_{SB}'' and U_{SC}'') provided on lines 53, 55, 57. For

example, if E_A is greater than zero, i.e., U_A'' is greater than U_T , the output of comparator 48 assumes a value $U_{SA}'' = 1$. Switch S1 is closed and S1* is opened.

An amplitude modulation index m_A is defined as a ratio of the peak value of a sinusoidal reference voltage to the peak value U_{TP} . For $m_A < 1$, U_A and U_B and U_C , as waveforms 81, 82, 83, are shown in Fig. 2. The uppermost portion of waveforms 81, 82, 83, the maximum of U_A and U_B and U_C , is shown in bold as waveform 84, U_{MAX} . The triangle peak signal U_{TP} is marked on the voltage axis. Figs. 2 and 3 are on a common time line and are divided into three sections "A", "B", "C".

The difference signal (U_{DD}) produced on line 32 by the summer 24 and equal to the difference between U_{TP} and U_{MAX} is shown by a waveform 80 in Fig. 3. U_{DD} causes $U_{O'O}$ to vary. $U_{O'O}$ is the potential difference between the load midpoint, O', and the supply midpoint, O.

The microprocessor-based blanking interval voltage deviation compensator 102 is responsive on lines 36, 38, 40 to the first augmented reference voltage U_X' (where X is A, B, or C) and on lines 103, 105, 107 to reference currents on lines 104, 106, 108, I_A, I_B, I_C associated with those reference voltages and to the triangle peak signals $\pm U_{TP}$ on line 110. It provides on lines 116, 114, 112 three second augmented reference voltage signals (U_A'' and U_B'' and U_C'') for each of the bridge legs 56, 58, 60. t_A , T_C and U_{DC} on lines 118, 120, 122, (the blanking interval, the carrier time period, and DC bus voltage, respectively) are also provided to the blanking interval voltage deviation compensator 102 for providing a blanking interval voltage compensation voltage ΔU_X .

Fig. 4 shows the logic routine for determining the value of the second augmented reference voltage signals (U_A'' and U_B'' and U_C''). For an inverter, voltage deviation in the inverter output is compensated. The routine of Fig. 4 provides that if the reference current I_X (where X is A, B, or C and I_A is associated with U_A , I_B is associated with U_B , etc.) is positive, the blanking interval compensation voltage ΔU_X is added to the first augmented reference voltage U_X' . On the other hand, if the reference current I_X is negative, the same blanking interval compensation voltage ΔU_X is subtracted from the first augmented reference voltage U_X' .

An inverter leg 56, 58, 60, is defined as the PWM circuit and the associated bridge leg. In Fig. 1 there are three inverter legs. Saturation of, for example, the inverter leg 56 occurs when an increase in input reference voltage to the PWM circuit does not yield any greater bridge output voltage. For example, an increase in U_A' beyond $\pm U_{TP}$ will not yield any greater inverter output voltage from that leg 56.

The routine compensates blanking interval voltage deviation if the inverter leg 56 is not saturated and compensation would not cause the inverter leg to

saturate. Because PWM 3 saturates if U_X' exceeds $\pm U_{TP}$, one can determine if the inverter leg is saturated by determining whether U_X' is inside or outside $\pm U_{TP}$. One can also determine if compensation is going to cause saturation by determining whether E_X is within $\pm U_{TP}$.

The routine is entered at step 401. If U_X' is greater than or equal to the triangle peak U_{TP} (a step 404 affirmative), inverter leg is saturated and therefore there is no compensation of a blanking interval voltage, and the input U_X'' to PWM 2 is set equal to U_{TP} (a step 406). A similar result is generated if the first augmented reference voltage U_X' is equal to or less than $-U_{TP}$ (a step 404 negative and step 408 affirmative); U_X'' is then set to $-U_{TP}$ (a step 410). If the step 408 is answered negative, the inverter leg is not in saturation. From step 408 negative, the routine proceeds to step 412 where a sum E_X is calculated between (a) U_X' and (b) the blanking interval compensation voltage ($\Delta U_X = U_{DC} * [t\Delta/TC]$) multiplied by the signum function of the reference current I_X . If the sum E_X is less than or equal to $-U_{TP}$ (a step 414 affirmative), or greater than or equal to U_{TP} (a step 414 negative and a step 416 affirmative), there is no compensation because doing so would put inverter leg into saturation; U_X'' is the same as U_X' (a step 418). If the sum E_X is within the bounds set by U_{TP} and $-U_{TP}$ (a step 414 negative and a step 416 negative), compensating would not cause saturation; therefore the blanking interval voltage deviation is compensated by setting U_X'' to E_X (a step 420). Because the signum function provides a value of 1 for a positive input and -1 for a negative input, a voltage equal to the calculated voltage deviation is added to U_X' if the reference current I_X is greater than zero, and that voltage is subtracted from U_X' if the reference current I_X is less than zero.

The invention does not compensate blanking interval voltage deviation all the time, but only when it is necessary, for example, for a time equivalent to 240° of the reference phase voltage U_X . The invention may be implemented in an inverter circuit as in Fig. 1 or as a converter in Fig. 5. The balanced load elements 70 are replaced by inductors and three sinusoidal power sources U_D , U_E , and U_F .

Although the invention has been shown and described with respect to a best mode embodiment thereof, it should be understood by those skilled in the art that the foregoing and various other changes, omissions, and additions in the form and detail thereof may be made therein without departing from the scope of the invention which is defined by the claims.

Claims

1. A method for compensating a voltage deviation in the output voltage of a pulse-width-modulation

(PWM) voltage inverter or converter, said inverter or converter including a bridge (5) having at least three legs (A, B, C), said PWM using a carrier signal (U_T), the magnitude of the carrier signal having a positive peak ($+U_{TP}$) and negative peak ($-U_{TP}$), comprising the steps of:

providing a plurality of reference current signals (103, 105, 107), each displaced by a phase angle from the adjacent reference current, one reference current associated with each leg (A, B, C);

providing a plurality of first augmented reference voltage signals (U_A' , U_B' , U_C'), each first augmented reference voltage being associated with a single one of said reference current signals;

calculating a blanking interval compensation voltage signal (U_X) in response to a DC bus voltage (U_{DC}) of said inverter or converter, a blanking interval, and a period (T_C) of said carrier signal; characterised by

adding the blanking interval compensation voltage signal to each of said first augmented reference voltage signals when said inverter or converter is not saturated and said step of adding will not cause said inverter or converter to saturate, thereby providing a plurality of second augmented reference signals (U_A'' , U_B'' , U_C''); and

providing said second augmented reference signals to a pulse-width modulation circuit (3).

2. A method as claimed in claim 1, wherein said step of adding comprises:

forming the product of said blanking interval compensation voltage signal and the polarity of the magnitude of one of said reference currents;

summing said product with one of said first augmented reference voltage signal to provide a sum;

comparing said positive peak to said first augmented reference voltage signal and providing said second augmented reference voltage signal at a value equal to the positive peak when said first augmented reference voltage signal is greater than said positive peak;

comparing said negative peak to said first augmented reference voltage signal and providing said second augmented reference voltage signal at a value equal to the negative peak when said first augmented reference voltage signal is less than said negative peak;

comparing said sum with said positive peak and providing said second augmented reference voltage signal at a value equal to the magnitude of said first augmented reference voltage signal when said positive peak is less than said



saturate. Because PWM 3 saturates if U_X' exceeds $\pm U_{TP}$, one can determine if the inverter leg is saturated by determining whether U_X' is inside or outside $\pm U_{TP}$. One can also determine if compensation is going to cause saturation by determining whether E_X is within $\pm U_{TP}$.

The routine is entered at step 401. If U_X' is greater than or equal to the triangle peak U_{TP} (a step 404 affirmative), inverter leg is saturated and therefore there is no compensation of a blanking interval voltage, and the input U_X'' to PWM 2 is set equal to U_{TP} (a step 406). A similar result is generated if the first augmented reference voltage U_X' is equal to or less than $-U_{TP}$ (a step 404 negative and step 408 affirmative); U_X'' is then set to $-U_{TP}$ (a step 410). If the step 408 is answered negative, the inverter leg 56 is not in saturation. From step 408 negative, the routine proceeds to step 412 where a sum E_X is calculated between (a) U_X' and (b) the blanking interval compensation voltage ($\Delta U_X = U_{DC} * [t\Delta/TC]$) multiplied by the signum function of the reference current I_X . If the sum E_X is less than or equal to $-U_{TP}$ (a step 414 affirmative), or greater than or equal to U_{TP} (a step 414 negative and a step 416 affirmative), there is no compensation because doing so would put inverter leg into saturation; U_X'' is the same as U_X' (a step 418). If the sum E_X is within the bounds set by U_{TP} and $-U_{TP}$ (a step 414 negative and a step 416 negative), compensating would not cause saturation; therefore the blanking interval voltage deviation is compensated by setting U_X'' to E_X (a step 420). Because the signum function provides a value of 1 for a positive input and -1 for a negative input, a voltage equal to the calculated voltage deviation is added to U_X' if the reference current I_X is greater than zero, and that voltage is subtracted from U_X' if the reference current I_X is less than zero.

The invention does not compensate blanking interval voltage deviation all the time, but only when it is necessary, for example, for a time equivalent to 240° of the reference phase voltage U_X . The invention may be implemented in an inverter circuit as in Fig. 1 or as a converter in Fig. 5. The balanced load elements 70 are replaced by inductors and three sinusoidal power sources U_D , U_E , and U_F .

Although the invention has been shown and described with respect to a best mode embodiment thereof, it should be understood by those skilled in the art that the foregoing and various other changes, omissions, and additions in the form and detail thereof may be made therein without departing from the scope of the invention which is defined by the claims.

Claims

1. A method for compensating a voltage deviation in the output voltage of a pulse-width-modulation

(PWM) voltage inverter or converter, said inverter or converter including a bridge (5) having at least three legs (A, B, C), said PWM using a carrier signal (U_T), the magnitude of the carrier signal having a positive peak ($+U_{TP}$) and negative peak ($-U_{TP}$), comprising the steps of:

providing a plurality of reference current signals (103, 105, 107), each displaced by a phase angle from the adjacent reference current, one reference current associated with each leg (A, B, C);

providing a plurality of first augmented reference voltage signals (U_A' , U_B' , U_C'), each first augmented reference voltage being associated with a single one of said reference current signals;

calculating a blanking interval compensation voltage signal (U_X) in response to a DC bus voltage (U_{DC}) of said inverter or converter, a blanking interval, and a period (T_C) of said carrier signal; characterised by

adding the blanking interval compensation voltage signal to each of said first augmented reference voltage signals when said inverter or converter is not saturated and said step of adding will not cause said inverter or converter to saturate, thereby providing a plurality of second augmented reference signals (U_A'' , U_B'' , U_C''); and

providing said second augmented reference signals to a pulse-width modulation circuit (3).

2. A method as claimed in claim 1, wherein said step of adding comprises:

forming the product of said blanking interval compensation voltage signal and the polarity of the magnitude of one of said reference currents;

summing said product with one of said first augmented reference voltage signal to provide a sum;

comparing said positive peak to said first augmented reference voltage signal and providing said second augmented reference voltage signal at a value equal to the positive peak when said first augmented reference voltage signal is greater than said positive peak;

comparing said negative peak to said first augmented reference voltage signal and providing said second augmented reference voltage signal at a value equal to the negative peak when said first augmented reference voltage signal is less than said negative peak;

comparing said sum with said positive peak and providing said second augmented reference voltage signal at a value equal to the magnitude of said first augmented reference voltage signal when said positive peak is less than said



sum;

comparing said sum with said negative peak and providing said second augmented reference voltage signal at a value equal to the magnitude of said first augmented reference voltage signal when said negative peak is less than said sum;

providing said second augmented reference voltage signal at a value equal to said sum if said sum is neither greater than nor less than said positive and negative peaks.

3. A device for compensating a voltage deviation in the output voltage of a pulse-width-modulation (PWM) inverter or converter, said inverter or converter including a bridge having at least three legs (A, B, C), said PWM using a carrier signal (U_T), the magnitude of the carrier signal having a positive peak ($+U_{TP}$) and a negative peak ($-U_{TP}$), comprising:

means for providing a plurality of reference current signals (103, 105, 107), each displaced by a phase angle from the adjacent reference current, one reference current associated with each leg (A, B, C);

means for providing a plurality of first augmented reference voltage signals (U_A' , U_B' , U_C'), each first augmented reference voltage being associated with a single one of said reference current signals;

means for calculating a blanking interval compensation voltage signal (U_X) in response to a DC bus voltage of said inverter or converter, a blanking interval and a period (T_C) of said carrier signal;

means for providing the product of said blanking interval voltage deviation compensation signal and the polarity of the magnitude of one of said reference currents;

means for summing said product with said one of said first augmented reference voltage signal and providing a sum;

means for providing a plurality of second augmented reference voltage signals (U_A'' , U_B'' , U_C'') to a pulse width modulation circuit (3), characterised by

first means (102) for comparing said positive peak to each of said first augmented reference voltage signals and providing said second augmented reference voltage signals at a value equal to the positive peak when said first augmented reference voltage signal is greater than said positive peak;

second means (102) for comparing said negative peak to said first augmented reference voltage signal and providing said second augmented reference voltage signal at a value equal to the negative peak when said first augmented

reference voltage signal is less than said negative peak;

third means (102) for comparing said sum with said positive peak and providing a second augmented reference voltage signal at a value equal to the magnitude of said first augmented reference voltage signal when said positive peak is less than said sum;

fourth means (102) for comparing said sum with said negative peak and providing said second augmented reference voltage signal at a value equal to the magnitude of said first augmented reference voltage signal when said negative peak is less than said sum;

means (102) for providing said second augmented reference voltage signal at a value equal to said sum if said sum is neither greater than nor less than said positive and negative peaks.

Patentansprüche

1. Verfahren zum Kompensieren einer Spannungsabweichung in der Ausgangsspannung eines Impulsbreitenmodulations-(PWM-)Spannungswechselrichters oder -Gleichrichters, wobei der Wechselrichter oder Gleichrichter eine Brücke (5) mit mindestens drei Zweigen (A, B, C) enthält, die PWM eine Trägersignal (U_T) verwendet, dessen Betrag eine positive Spitze ($+U_{TP}$) und eine negative Spitze ($-U_{TP}$) aufweist, umfassend die Schritte:

- Bereitstellen einer Mehrzahl von Referenzstromsignalen (103, 105, 107), von denen jedes um einen Phasenwinkel gegenüber dem benachbarten Referenzstrom versetzt ist und jedem Zweig (A, B, C) ein Referenzstrom zugeordnet ist;
- Bereitstellen einer Mehrzahl von ersten erhöhten Referenzspannungssignalen (U_A' , U_B' , U_C'), von denen jede erste erhöhte Referenzspannung einem einzigen der Referenzstromsignale zugeordnet ist;
- Berechnen eines Austastintervallkompensationsspannungssignals (U_X) in Abhängigkeit einer Gleichstrommaschinenenspannung (U_{OC}) des Wechselrichters oder Gleichrichters, eines Austastintervalls und einer Periodendauer (T_C) des Trägersignals; gekennzeichnet durch
- das Addieren des Austastintervallkompensationsspannungssignals auf jedes der ersten erhöhten Referenzspannungssignale, wenn der Wechselrichter oder Gleichrichter nicht gesättigt ist, wobei dieser Addierschritt nicht verursacht, daß der Wechselrichter oder Gleichrichter in Sättigung geht,



um dadurch eine Mehrzahl von zweiten erhöhten Referenzsignalen (U_A'' , U_B'' , U_C'') zu erhalten; und

- Liefern der zweiten erhöhten Referenzsignale an eine Impulsbreitenmodulationsschaltung (3).

2. Verfahren nach Anspruch 1, bei dem der Addierschritt umfaßt:

- Bilden des Produkts des Austastintervallkompensationsspannungssignals und der Polarität des Betrags einer der Referenzströme; 10
- Summieren des Produkts mit einem der ersten erhöhten Referenzspannungssignale, um eine Summe bereitzustellen; 15
- Vergleichen der positiven Spitze mit dem ersten erhöhten Referenzspannungssignal und Bereitstellen des zweiten erhöhten Referenzspannungssignals mit einem Wert gleich der positiven Spitze, wenn das erste erhöhte Referenzspannungssignal größer als die positive Spitze ist; 20
- Vergleichen der negativen Spitze des ersten erhöhten Referenzspannungssignals und Bereitstellen des erhöhten Referenzspannungssignals mit einem Wert gleich der negativen Spitze, wenn das erste erhöhte Referenzspannungssignal geringer ist als die negative Spitze; 25
- Vergleichen der Summe mit der positiven Spitze und Bereitstellen des zweiten erhöhten Referenzspannungssignals mit einem Wert gleich dem Betrag des ersten erhöhten Referenzspannungssignals, wenn die positive Spitze kleiner als die Summe ist; 30
- Vergleichen der Summe mit der negativen Spitze und Bereitstellen des zweiten erhöhten Referenzspannungssignals mit einem Wert gleich dem Betrag des ersten erhöhten Referenzspannungssignals, wenn die negative Spitze kleiner als die Summe ist; 40
- Bereitstellen des zweiten erhöhten Referenzspannungssignals mit einem Wert gleich der Summe, falls die Summe weder größer noch kleiner als die positive beziehungsweise die negative Spitze ist. 45

3. Vorrichtung zum Kompensieren einer Spannungsabweichung in der Ausgangsspannung eines Impulsbreitenmodulations-(PWM-)Wechselrichters oder -Gleichrichters, wobei der Wechselrichter oder Gleichrichter eine Brücke mit mindestens drei Zweigen (A, B, C) aufweist, die PWM ein Trägersignal (U_T) verwendet, dessen Betrag eine positive Spitze ($+U_{TP}$) und eine negative

Spitze ($-U_{TP}$) besitzt, umfassend:

- eine Einrichtung zum Bereitstellen einer Mehrzahl von Referenzstromsignalen (103, 105, 107), die jeweils um einen Phasenwinkel gegenüber dem benachbarten Referenzstrom versetzt sind und von denen jeweils ein Referenzstrom einem Zweig (A, B, C) zugeordnet ist;
- eine Einrichtung zum Bereitstellen einer Mehrzahl erster erhöhter Referenzspannungssignale (U_A' , U_B' , U_C'), wobei jede erste erhöhte Referenzspannung einem einzigen der Referenzstromsignale zugeordnet ist;
- eine Einrichtung zum Berechnen eines Austastintervallkompensationsspannungssignals (U_X) in Abhängigkeit einer Gleichstromschienenspannung des Wechselrichters oder Gleichrichters, eines Austastintervalls und einer Periodendauer (T_C) des Trägersignals;
- eine Einrichtung zum Bereitstellen des Produkts des Austastintervallspannungsabweichungskompensationssignals und der Polarität des Betrags eines der Referenzströme;
- eine Einrichtung zum Summieren des Produkts mit dem einen der ersten erhöhten Referenzspannungssignale, um eine Summe bereitzustellen;
- eine Einrichtung zum Bereitstellen einer Mehrzahl zweiter erhöhter Referenzspannungssignale (U_A'' , U_B'' , U_C'') für eine Impulsbreitenmodulationsschaltung (3), gekennzeichnet durch
- eine erste Einrichtung (102) zum Vergleichen der positiven Spitze jeder der ersten erhöhten Referenzspannungssignale und zum Bereitstellen der zweiten erhöhten Referenzspannungssignale mit einem Wert gleich der positiven Spitze, wenn das erste erhöhte Referenzspannungssignal größer als die positive Spitze ist;
- eine zweite Einrichtung (102) zum Vergleichen der negativen Spitze mit dem ersten erhöhten Referenzspannungssignal und zum Bereitstellen des zweiten erhöhten Referenzspannungssignals mit einem Wert gleich der negativen Spitze, wenn das erste erhöhte Referenzspannungssignal kleiner als die negative Spitze ist;
- eine dritte Einrichtung (102) zum Vergleichen der Summe mit der positiven Spitze und zum Bereitstellen eines zweiten erhöhten Referenzspannungssignals mit einem Wert gleich dem Betrag des ersten erhöhten Referenzspannungssignals, wenn die positive Spitze kleiner als die Summe ist;



- une quatrième Einrichtung (102) zum Vergleichen der Summe mit der negativen Spitze und zum Bereitstellen eines zweiten erhöhten Referenzspannungssignals mit einem Wert gleich dem Betrag des ersten erhöhten Referenzspannungssignals, wenn die negative Spitze kleiner als die Summe ist;
- eine Einrichtung (102) zum Bereitstellen des zweiten erhöhten Referenzspannungssignals mit einem Wert gleich der Summe, falls die Summe weder größer noch kleiner als die positive bzw. die negative Spitze ist.

Revendications

1. Procédé pour compenser une déviation de tension dans la tension de sortie d'un onduleur ou convertisseur de tension à modulation d'impulsions en largeur (PWM), ledit onduleur ou convertisseur comprenant un pont (5) ayant au moins trois branches (A, B, C), ladite modulation PWM utilisant un signal de porteuse (U_T), l'amplitude du signal de porteuse ayant un pic positif ($+U_{TP}$) et un pic négatif ($-U_{TP}$), comprenant les étapes consistant à :

fournir une pluralité de signaux de courant de référence (103, 105, 107), chacun décalé d'un angle de phase par rapport au courant de référence adjacent, un courant de référence associé à chaque branche (A, B, C) ;

fournir une pluralité de premiers signaux de tension de référence augmentée (U_A' , U_B' , U_C'), chaque première tension de référence augmentée étant associée à un seul desdits signaux de courant de référence ;

calculer un signal de tension compensatrice d'intervalle de suppression (U_X) en réponse à une tension de bus continue (U_{OC}) dudit onduleur ou convertisseur, un intervalle de suppression, et une période (T_C) dudit signal de porteuse ; caractérisé par le fait de

ajouter la tension compensatrice d'intervalle de suppression à chacun desdits premiers signaux de tension de référence augmentée lorsque ledit onduleur ou convertisseur n'est pas saturé, et ladite étape d'ajout ne provoquera pas la saturation dudit onduleur ou convertisseur, fournissant ainsi une pluralité de deuxième signaux de référence augmentés (U_A'' , U_B'' , U_C''); et

fournir lesdits deuxième signaux de référence augmentés à un circuit (3) de modulation d'impulsions en largeur.

2. Procédé selon la revendication 1, dans lequel l'étape d'addition comprend le fait de :

former le produit dudit signal de tension compensatrice d'intervalle de suppression et de

la polarité de l'amplitude de l'un desdits courants de référence ;

additionner ledit produit audit un desdits premiers signaux de tension de référence augmentée, pour fournir une somme ;

comparer ledit pic positif audit premier signal de référence augmentée et fournir ledit deuxième signal de tension de référence augmentée à une valeur égale au pic positif lorsque ledit premier signal de tension de référence augmentée est supérieur audit pic positif ;

comparer ledit pic négatif audit premier signal de référence augmentée et fournir ledit deuxième signal de tension de référence augmentée à une valeur égale au pic négatif lorsque ledit premier signal de tension de référence augmentée est inférieur audit pic négatif ;

comparer ladite somme audit pic positif et fournir ledit deuxième signal de tension de référence augmentée à une valeur égale à l'amplitude dudit premier signal de tension de référence augmentée lorsque ledit pic positif est inférieur à ladite somme ;

comparer ladite somme audit pic négatif et fournir ledit deuxième signal de tension de référence augmentée à une valeur égale à l'amplitude dudit premier signal de tension de référence augmentée lorsque ledit pic négatif est inférieur à ladite somme ;

fournir ledit deuxième signal de tension de référence augmentée à une valeur égale à ladite somme si ladite somme n'est ni supérieure ni inférieure auxdits pics positif et négatif.

3. Dispositif pour compenser une déviation de tension dans la tension de sortie d'un onduleur ou convertisseur de tension à modulation d'impulsions en largeur (PWM), ledit onduleur ou convertisseur comprenant un pont ayant au moins trois branches (A, B, C), ladite modulation PWM utilisant un signal de porteuse (U_T), l'amplitude du signal de porteuse ayant un pic positif ($+U_{TP}$) et un pic négatif ($-U_{TP}$), comprenant :

un moyen pour fournir une pluralité de signaux de courant de référence (103, 105, 107), chacun décalé d'un angle de phase par rapport à un courant de référence adjacent, un courant de référence associé à chaque branche (A, B, C) ;

un moyen pour fournir une pluralité de premiers signaux de tension de référence augmentée (U_A' , U_B' , U_C'), chaque première tension de référence augmentée étant associée à un seul desdits signaux de courant de référence ;

un moyen pour calculer un signal de tension compensatrice d'intervalle de suppression (U_X) en réponse à une tension de bus continue dudit onduleur ou convertisseur, un intervalle de suppression, et une période (T_C) dudit signal de



porteuse ;

un moyen pour fournir le produit dudit signal de tension compensatrice d'intervalle de suppression et de la polarité de l'amplitude de l'un desdits courants de référence ;

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un moyen pour additionner ledit produit audit un desdits premiers signaux de tension de référence augmentée, et fournir une somme ;

un moyen pour fournir une pluralité de deuxièmes signaux de tension de référence augmentée (U_A'' , U_B'' , U_C'') à un circuit (3) de modulation d'impulsions en largeur, caractérisé par :

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un premier moyen (102) pour comparer ledit pic positif audit premier signal de référence augmentée et fournir ledit deuxième signal de tension de référence augmentée à une valeur égale au pic positif lorsque ledit premier signal de tension de référence augmentée est supérieur audit pic positif ;

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un deuxième moyen (102) pour comparer ledit pic négatif audit premier signal de référence augmentée et fournir ledit deuxième signal de tension de référence augmentée à une valeur égale au pic négatif lorsque ledit premier signal de tension de référence augmentée est inférieur audit pic négatif ;

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un troisième moyen (102) pour comparer ladite somme audit pic positif et fournir ledit deuxième signal de tension de référence augmentée à une valeur égale à l'amplitude dudit premier signal de tension de référence augmentée lorsque ledit pic positif est inférieur à ladite somme ;

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un quatrième moyen (102) pour comparer ladite somme audit pic négatif et fournir ledit deuxième signal de tension de référence augmentée à une valeur égale à l'amplitude dudit premier signal de tension de référence augmentée lorsque ledit pic négatif est inférieur à ladite somme ;

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un moyen (102) pour fournir ledit deuxième signal de tension de référence augmentée à une valeur égale à ladite somme si ladite somme n'est ni supérieure ni inférieure auxdits pics positif et négatif.

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