

CONTROL SYSTEM FOR VOLTAGE-SOURCE PULSE WIDTH
MODULATION STEP-UP CONVERTER

FIELD OF THE INVENTION

5 This invention relates to a control system for a voltage-source PWM (Pulse Width Modulation) step-up converter connected to a power supply through a reactor.

BACKGROUND OF THE INVENTION

10 There has been already proposed a frequency converter including a power supply side converter for converting an a.c. power delivered from an a.c. power supply through a reactor to a d.c. power, and a motor side converter for delivering a variable voltage and variable frequency a.c. power to an a.c. motor, both
15 converters being comprised of a voltage-source PWM (Pulse Width Modulation) converter, d.c. terminals of the both converter, d.c. terminals of the both converters being connected to each other, a smoothing capacitor being connected between positive and negative terminals of the
20 both converters. This frequency converter can attain an improvement in a power-factor when viewed from an a.c. power supply, i.e., power-factor on the side of power supply, and can carry out delivery and receipt of a power during power running of a motor and a power during
25 regenerative running thereof.

 When a load current flows in a frequency converter of this kind, a voltage drop V_L is produced in a reactor connected between the a.c. power supply and the power supply side converter. The power supply side converter
30 must compensate such a voltage drop as well to perform a control operation so that its output voltage becomes equal to a predetermined value. Assuming that a power-factor on the power supply is designated by ϕ and the relationship expressed as $\phi \neq 1$ holds, this voltage drop
35 V_L is produced at a phase lagging by an angle of 90 degrees with respect to the power supply voltage. When an attempt is made to compensate voltage drop V_L produced

at a phase lagging by an angle of 90 degrees by using the power supply side converter to control its output voltage so that it is equal to a predetermined value, the control circuit for the power supply side converter
5 would have to handle a larger control signal as a vector. Particularly in the case where a load current is large, since the reactor voltage drop V_L also become large, the control signal also becomes large, resulting in the possibility that the control signal exceeds above
10 the linear control range of the control circuit to reach the saturation range. When the operation mode of the control circuit has reached the saturation range, there occurs an extraordinary state in control such that a d.c. voltage on the power supply side converter is
15 lowered during power running and is raised during regenerative running.

An object of this invention is to provide a control system for a voltage-source PWM step-up converter capable of carrying out stable control without
20 causing an extraordinary change in state irrespective of load current.

SUMMARY OF THE INVENTION

According to the invention there is provided a control system for a voltage-source pulse width
25 modulation step-up converter (hereinafter abbreviated as a PWM converter) comprising:

- a reactor connected in series between an a.c. power supply and an a.c. terminal of said PWM converter,
- a smoothing capacitor connected between d.c.
30 terminals of said PWM converter,
- means for detecting an input voltage applied to said reactor,
- means for detecting a d.c. voltage across said smoothing capacitor,
- 35 means for detecting a load current flowing in said PWM converter,
- means for setting a voltage reference with respect to said PWM converter,

means for outputting a current amplitude reference on the basis of a deviation between said voltage reference and said d.c. voltage,

5 means for outputting a current reference synchronous with said input voltage to said reactor and having an amplitude corresponding to said current amplitude reference,

means for outputting a voltage command for allowing said load current to be in correspondence with
10 said current reference,

means for outputting a voltage compensation command leading said input voltage to said reactor by a phase angle of 90 degrees and having an amplitude corresponding to said current amplitude reference.

15 means for calculating a vector sum of said voltage command and said voltage compensation command to output said vector sum as a PWM control command, and

means for effecting a PWM control of said PWM converter on the basis of said PWM control command.

20 In the control system according to the invention means for compensating reactor voltage drop V_L is provided in a control circuit. Thus, even in the case where a load current becomes large, hence the reactor voltage drop V_L becomes large, there is no
25 possibility that the control signal becomes large to exceed above the linear control range of the control circuit to reach the saturation range. Accordingly, even at the time of power running or at the time of regenerative running, a stable d.c. voltage can be
30 obtained at all times.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. 1 is a block diagram showing an embodiment of a control system for a voltage-source PWM
35 step-up converter according to this invention,

FIG. 2 is a vector diagram for explaining the operation of the control system shown in FIG. 1, and

FIG. 3 is a circuit diagram showing a frequency converter to which this invention is applied.

5 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 3, there is shown a circuit configuration of a frequency converter to which this invention is applied. A controlled a.c. power is delivered from a commercial a.c. power supply 1 to an
10 a.c. motor 6, e.g., an induction motor through a reactor 2, a power supply side converter 3, a smoothing capacitor 4, and a motor side converter 5. The power supply side converter 3 and the motor side converter 5 have the same circuit configuration. Each arm of respective converters
15 is composed of switching elements of self-quenching elements, e.g., transistors or GTOs (Gate Turn Off Thyristors), etc., and diodes connected antiparallel therewith. In this figure, transistors are illustrated as the respective switching elements. While controlling
20 a voltage of the d.c. circuit, i.e., a voltage across the smoothing capacitor 4 so that it becomes equal to a predetermined value, this frequency converter can deliver a power from the a.c. power supply 1 to the a.c. motor 6 through the power supply side converter 3 and the motor
25 side converter 5 during power running, and can, in contrast with the above, regenerate a power from the a.c. motor 6 to the a.c. power supply 1 through the motor side converter 5 and the power side converter 3, thus permitting a power factor on the side of the power supply
30 to be satisfactory. The power supply side converter 3 can perform a so-called step-up control to adjust a d.c. circuit voltage (capacitor voltage) so that this voltage becomes equal to a predetermined value higher than a voltage crest or peak value of the a.c. power supply 1 in
35 cooperation with the reactor 2 and the smoothing capacitor 4. This invention is concerned with a control

system for the power supply side converter 3 in such a frequency converter.

Referring to FIG. 1, there is shown a control system of this invention used for the power supply side
5 converter 3.

At an adder 7, a voltage reference V^* set by a voltage reference setter 8 is compared with an actual voltage V detected by a voltage detector 9. A deviation ΔV obtained is input to a voltage controller (AVR) 10.
10 The voltage controller 10 outputs, in the form of a d.c. signal, a current amplitude reference $|I^*|$ allowing the deviation to be equal to zero, i.e., allowing an actual voltage V to be in correspondence with the voltage reference V^* . A voltage of the a.c. power supply 1,
15 i.e., a power supply side voltage of the reactor 2 is detected by a voltage detector 11. Thus, a first sine-wave reference generator 12 generates a first sine wave reference of a digital signal synchronous with a voltage detected. Further, a second sine-wave reference
20 generator 22 generates a second sine wave reference of a digital signal leading the first sine wave reference by a phase angle of 90 degrees. The first sine wave reference generated by the first sine-wave reference generator 12 is input to a first multiplying D/A (digital-to-analog)
25 converter 13. Further, the second sine wave reference generated by the second sine-wave reference generator 22 is input to a second multiplying D/A converter 23. The first D/A converter 13 outputs, in the form of an analog signal, a current reference I_U^* corresponding to a
30 product of the sine wave reference from the sine-wave reference generator 12 and a current amplitude reference $|I^*|$ from the voltage controller 10. On the other hand, the second D/A converter 23 outputs a voltage compensation command V_{LC} proportional to a product of the
35 sine wave reference leading in phase from the sine-wave reference generator 22 and the current amplitude reference $|I^*|$ from the voltage controller 10. At an

adder 14, the current reference I_u^* from the first D/A converter 13 is compared with a load current I detected by a current detector 16. A deviation obtained is input to a current controller (ACR) 17. The current controller
 5 17 outputs a voltage command V_A for allowing the input deviation to be equal to zero. The voltage command V_A from the current controller 17 and the voltage compensation command V_{LC} from the D/A converter 23 are both delivered to an adder 18, at which summation of the
 10 both commands is performed as a vector. The sum (vector sum) thus obtained is delivered to the first input terminal of a PWM comparator 20 as a PWM control command V_B (see FIG. 2). To the PWM comparator 20, a carrier wave signal of a triangular wave generated by an
 15 oscillator 19 is input as a second input signal. The PWM comparator 20 responds to the both input signals to output a PWM control signal to control an ON/OFF operation of respective switching elements constituting the power supply side converter 3.

20 The operation of the control system shown in FIG. 1 will now be described.

As previously described, the phase of the reactor voltage drop V_L lags by an angle of substantially 90 degrees with respect to the output voltage of the a.c. power supply 1. On the other hand, the phase of the sine
 25 wave reference output from the sine-wave reference generator 22 leads by an angle of 90 degrees with respect to the output voltage of the a.c. power supply 1. Accordingly, the voltage compensation command V_{LC} output from the D/A converter 23 has a relationship such that
 30 its phase is opposite to that of the reactor voltage drop V_L , i.e., a relationship such that there is a phase difference of 180 degrees (see FIG. 2), and has an amplitude corresponding to the current amplitude
 35 reference $|I^*|$, i.e., the load current I .

In accordance with the control system shown in FIG. 1, where a load current I flows through the reactor 2,

its voltage drop V_L can be canceled by the voltage compensation command V_{LC} obtained by the sine-wave reference generator 22 and the D/A converter 23. By providing a smaller PWM control command V_B is provided in
5 this way. Thus, a PWM control of the power side converter 3 is carried out through the PWM comparator 20 and the base drive circuit 21 in accordance with this PWM control command V_B . As is clear from the foregoing description, this invention can carry out a stable
10 control without causing an extraordinary state in control irrespective of the load current I to output a stable d.c. voltage.

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CLAIMS

1. A control system for a voltage-source pulse width modulation step-up converter (hereinafter abbreviated as a PWM converter) comprising:
 - 5 a reactor connected in series between an a.c. power supply and an a.c. terminal of said PWM converter,
 - a smoothing capacitor connected between d.c. terminals of said PWM converter,
 - means for detecting an input voltage applied to
 - 10 said reactor,
 - means for detecting a d.c. voltage across said smoothing capacitor,
 - means for detecting a load current flowing in said PWM converter,
 - 15 means for setting a voltage reference with respect to said PWM converter,
 - means for outputting a current amplitude reference on the basis of a deviation between said voltage reference and said d.c. voltage,
 - 20 means for outputting a current reference synchronous with said input voltage to said reactor and having an amplitude corresponding to said current amplitude reference,
 - means for outputting a voltage command for allowing
 - 25 said load current to be in correspondence with said current reference,
 - means for outputting a voltage compensation command leading said input voltage to said reactor by a phase angle



of 90 degrees and having an amplitude corresponding to said current amplitude reference,

means for calculating a vector sum of said voltage command and said voltage compensation command to output
5 said vector sum as a PWM control command, and

means for effecting a PWM control of said PWM converter on the basis of said PWM control command.

2. A control system as set forth in Claim 1, wherein said means for outputting said current reference is
10 composed of a sine-wave reference generator for outputting, as a sine wave reference, in the form of a digital signal, a sample value synchronous with said input voltage to said reactor and corresponding to an instantaneous value of said input voltage, and a digital-to-analog converter for
15 outputting, in the form of an analog signal, a signal corresponding to a product of an output signal from said sine-wave reference generator and said current amplitude reference.

3. A control system as set forth in Claim 1, wherein
20 said means for outputting voltage compensation command is composed of a sine-wave reference generator for outputting, as an input voltage sine wave reference, in the form of a digital signal, a sample value leading said input voltage to said reactor by a phase angle of 90 degrees and
25 corresponding to an instantaneous value of said input voltage to said reactor, and a multiplying digital-to-analog converter for outputting, in the form of an analog signal, a signal corresponding to a product of an output



signal from said sine-wave reference generator and said current amplitude reference.

4. A control system as set forth in Claim 1, wherein said means for carrying out PWM control includes an oscillator for generating a triangular carrier wave, and a PWM comparator responsive to said triangular carrier wave generated by said oscillator and said PWM control command to output a control command for carrying out an ON/OFF control of switching elements of said PWM converter.
- 10 5. A control system for a voltage-source PWM step-up converter substantially as hereinbefore described with reference to the accompanying drawings.
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