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Claims

1. A method of controlling the flow of current through a DC matrix converter (18) between a DC load (19) and a set of three-phase AC mains (a, b, c), said DC matrix converter comprising a plurality of top switches (at-, at+, bt-, bt+, ct-, ct+), each
 - 5 connected between a corresponding one of said AC mains and a first DC output (J) of said DC matrix converter, and a plurality of bottom switches (ab-, ab+, bb-, bb+, cb-, cb+), each connected between a corresponding one of said AC mains and a second DC output (K) of said DC matrix converter, comprising:
 - 10 operating said switches in a manner so that each switch, when operated to connect a corresponding one of said AC mains to a related specific one of said DC outputs, remains operated until another switch has operated to connect one of said AC mains to said specific DC output, and so that one of said top switches is operated
 - 15 contemporaneously with one of said bottom switches, said switches being operated in pairs, each pair including a top switch related to one AC main and a bottom switch related to an AC main other than said one AC main, and said switches also being operated in sets, each set including a top switch and a bottom switch both related to
 - 20 the same AC main;
 - characterized by:
 - providing a voltage command signal, V^* (52), indicative of the voltage to be provided by said DC output terminals to said load;
 - providing (53) a modulation command, m^* , as the ratio of
 - 25 said voltage command signal, V^* , to the instantaneous magnitude of voltage, V (57), of said AC mains in stationary d, q coordinates; and
 - providing an in-phase modulation command component, $m_q = m^* \cos\theta$ (71, 101) and a quadrature modulation command component $m_d = m^* \sin\theta$ (72, 102);



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- 30 providing (73) a quantity $m1 = \sqrt{3}md/2 - mq/2$ (103);
 providing a quantity $m2 = \sqrt{3}md/2 + mq/2$ (104);
 providing (56) an in-phase component, Vq , and a quadrature
 component, Vd , of the instantaneous AC mains voltage in orthogonal
 coordinates aligned with the phase of a given one of said AC mains
 35 (a); and
 providing, when $|Vd/\sqrt{3}| < |Vq|$ (125), a first fraction
 $d\alpha = -m1$ if $Vq > 0$ and $d\alpha = m1$ if $Vq < 0$, and a second fraction
 (115) $d\beta = m2$ if $Vq > 0$ (119) and $d\beta = -m2$ if $Vq < 0$;
 providing when $VdVq/\sqrt{3} > Vq^2$ (125), said first fraction $d\alpha$
 40 $= mq$ if $Vq > 0$ and $d\alpha = -mq$ if $Vq < 0$, and said second fraction
 $d\beta = m1$ (116) if $Vq > 0$ and $d\beta = -m1$ if $Vq < 0$ (117); and
 providing, when neither $|Vd/\sqrt{3}| < |Vq|$ nor $VdVq/\sqrt{3} > Vq^2$
 (116), said first fraction $d\alpha = -m2$ if $Vq > 0$ and $d\alpha = m2$ if $Vq <$
 0 , and said second fraction $d\beta = mq$ if $Vq > 0$ and $d\beta = -mq$ if Vq
 45 < 0 (118); and
 in each of a continuous sequence of modulation periods
 which are small compared with the period of voltage of said AC
 mains, operating a first pair of said switches for said first fraction,
 $d\alpha$, of said period, operating a second pair of said switches for said
 50 second fraction, $d\beta$, of said period, and operating a set of switches
 for the remainder of said period.

2. A method according to claim 1 wherein said first fraction
 of time precedes said second fraction of time within said modulation
 periods.

3. A method according to claim 1 wherein the remainder of
 said period follows said first and second fractions of time within said
 modulation periods.



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4. A method of controlling the flow of current through a DC matrix converter (18) between a DC load (19) and a set of three-phase AC mains (a, b, c), said DC matrix converter comprising a plurality of top switches (at-, at+, bt-, bt+, ct-, ct+), each
- 5 connected between a corresponding one of said AC mains and a first DC output (J) of said DC matrix converter, and a plurality of bottom switches, (ab-, ab+, bb-, bb+, cb-, cb+) each connected between a corresponding one of said AC mains and a second DC output (K) of said DC matrix converter, comprising:
- 10 operating said switches in a manner so that each switch, when operated to connect a corresponding one of said AC mains to a related specific one of said DC outputs, remains operated until another switch has operated to connect one of said AC mains to said specific DC output, and so that one of said top switches is operated
- 15 contemporaneously with one of said bottom switches, said switches being operated in pairs, each pair including a top switch related to one AC main and a bottom switch related to an AC main other than said one AC main, and said switches also being operated in sets, each set including a top switch and a bottom switch both related to
- 20 the same AC main;
- characterized by the improvement comprising:
- in each of a continuous sequence of modulation periods which are small compared with the period of voltage of said AC mains, operating a first pair of said switches for a first fraction, $d\alpha$,
- 25 of said period, operating a second pair of said switches for a second fraction, $d\beta$, of said period, and operating a set of switches for the remainder of said period;
- providing (56) an in-phase component, V_q , and a quadrature component, V_d , of the instantaneous AC mains voltage in orthogonal



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30 coordinates aligned with the phase of a given one of said AC mains (a);

if $V_d/\sqrt{3} > |V_q|$ (130), said first pair of switches include a top switch (Bt) connected to a third AC main, next advanced in phase from said given one of said AC mains, but if not, then if $V_q > 0$

35 (131), said first pair of switches include a top switch (At) connected to said given one of said AC mains, but if neither, then said first pair of switches include a top switch (Ct) connected to a second AC main, next delayed in phase from said given one of said AC mains;

if $V_d/\sqrt{3} > |V_q|$, said first pair of switches include a bottom switch (Bb) connected to said third AC main, but if not, then if $-V_q < 0$, said first pair of switches include a bottom switch connected to said given one of said AC mains (Ab), but if neither, then said first pair of switches include a bottom switch connected to said second AC main (Cb);

45 if $V_d/\sqrt{3} > |V_q|$, said second pair of switches include a top switch connected to said second main (Ct), but if not, then if $V_q > 0$, said second pair of switches include a top switch (At) connected to said given one of said AC mains, but if neither, then said second pair of switches include a top switch (Bt) connected to said third AC main; and

50 if $V_d/\sqrt{3} > |V_q|$, said second pair of switches include a bottom switch (Cb) connected to said second main, but if not, then if $V_q < 0$, said second pair of switches include a bottom switch (Ab) connected to said given one of said AC mains, but if neither, then

55 said second pair of switches include a bottom switch (Bb) connected to said third AC main.



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5. A method according to claim 4 wherein said first fraction of time (α) precedes said second fraction of time (β) within said modulation periods.

6. A method according to claim 4 wherein the remainder of said period follows said first (α) and second (β) fractions of time within said modulation periods.

7. A method of controlling the flow of current through a DC matrix converter (18) between a DC load (19) and a set of three-phase AC mains (a, b, c), said DC matrix converter comprising a plurality of top switches (at, -at, bt, -bt, ct, -ct), each connected
5 between a corresponding one of said AC mains and a first DC output (J) of said DC matrix converter, and a plurality of bottom switches (ab, -ab, bb, -bb, cb, -cb), each connected between a corresponding one of said AC mains and a second DC output (K) of said DC matrix converter, comprising:
10 operating said switches in a manner so that each switch, when operated to connect a corresponding one of said AC mains to a related specific one of said DC outputs, remains operated until another switch has operated to connect one of said AC mains to said specific DC output, and so that one of said top switches is operated
15 contemporaneously with one of said bottom switches, said switches being operated in pairs, each pair including a top switch related to one AC main and a bottom switch related to an AC main other than said one AC main, and said switches also being operated in sets, each set including a top switch and a bottom switch both related to
20 the same AC main;
characterized by:



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providing a voltage command signal, V^* (52), indicative of the voltage to be provided by said DC output terminals to said load;

25 providing (53) a modulation command, m^* , as the ratio of said voltage command signal, V^* , to the instantaneous magnitude of voltage, V , (57) of said AC mains in stationary d, q coordinates; and

providing an in-phase modulation command component, $m_q = m^* \cos\theta$ (71, 101) and a quadrature modulation command component $m_d = m^* \sin\theta$ (72, 102);

30 providing a quantity $m_1 = \sqrt{3}m_d/2 - m_q/2$ (103);

providing a quantity $m_2 = \sqrt{3}m_d/2 + m_q/2$ (104);

providing (56) an in-phase component, V_q , and a quadrature component, V_d , of the instantaneous AC mains voltage in orthogonal coordinates aligned with the phase of a given one of said AC mains

35 (a); and

providing, when $|V_d/\sqrt{3}| < |V_q|$ (125), a first fraction $d\alpha = -m_1$ if $V_q > 0$ and $d\alpha = m_1$ if $V_q < 0$, and a second fraction (115) $d\beta = m_2$ if $V_q > 0$ (119) and $d\beta = -m_2$ if $V_q < 0$;

40 providing when $V_d V_q \sqrt{3} > V_q^2$ (125), said first fraction $d\alpha = m_q$ if $V_q > 0$ and $d\alpha = -m_q$ if $V_q < 0$, and said second fraction $d\beta = m_1$ (116) if $V_q > 0$ and $d\beta = -m_1$ if $V_q < 0$ (117); and

45 providing, when neither $|V_d/\sqrt{3}| < |V_q|$ nor $V_d V_q \sqrt{3} > V_q^2$ (116), said first fraction $d\alpha = -m_2$ if $V_q > 0$ and $d\alpha = m_2$ if $V_q < 0$, and said second fraction $d\beta = m_q$ if $V_q > 0$ and $d\beta = -m_q$ if $V_q < 0$ (118); and

50 in each of a continuous sequence of modulation periods which are small compared with the period of voltage of said AC mains, operating a first pair of said switches for a first fraction, $d\alpha$, of said period, operating a second pair of said switches for a second fraction, $d\beta$, of said period, and operating a set of switches for the remainder of said period;



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and further comprising:

- if $V_d/\sqrt{3} > |V_q|$ (130), said first pair of switches include a top switch (Bt) connected to a third AC main, next advanced in phase from said given one of said AC mains, but if not, then if $V_q > 0$ (131), said first pair of switches include a top switch (At) connected to said given one of said AC mains, but if neither, then said first pair of switches include a top switch (Ct) connected to a second AC main, next delayed in phase from said given one of said AC mains;
- if $V_d/\sqrt{3} > |V_q|$, said first pair of switches include a bottom switch (Bb) connected to said third AC main, but if not, then if $-V_q < 0$, said first pair of switches include a bottom switch connected to said given one of said AC mains (Ab), but if neither, then said first pair of switches include a bottom switch connected to said second AC main (Cb);
- if $V_d/\sqrt{3} > |V_q|$, said second pair of switches include a top switch connected to said second main (Ct), but if not, then if $V_q > 0$, said second pair of switches include a top switch (At) connected to said given one of said AC mains, but if neither, then said second pair of switches include a top switch (Bt) connected to said third AC main; and
- if $V_d/\sqrt{3} > |V_q|$, said second pair of switches include a bottom switch (Cb) connected to said second main, but if not, then if $V_q < 0$, said second pair of switches include a bottom switch (Ab) connected to said given one of said AC mains, but if neither, then said second pair of switches include a bottom switch (Bb) connected to said third AC main.

8. A method according to claim 7 wherein said first fraction of time (α) precedes said second fraction of time (β) within said modulation periods.



9. A method according to claim 7 wherein the remainder of said period follows said first (α) and second (β) fractions of time within said modulation periods.