

WHAT IS CLAIMED IS:

1. A multi-quadrant multi-level cascaded converter connectable to a load, comprising:
 - a plurality of cells connected in series,
 - wherein each cell of the plurality of cell represents an H-bridge converter and comprises a plurality of bidirectional switches and a storage element; and
 - a hysteresis current control system coupled to the plurality of cells, wherein the control system is configured to control one or more of a shape and a level of current in the load.
2. The converter of claim 1, comprising four (4) quadrants and nine (9) output levels.
3. The converter of claim 2, comprising four (4) cells connected in series, and wherein each cell represents a four-quadrant H-bridge converter.
4. The converter of claim 3, wherein each cell of the plurality of cells comprises four (4) bidirectional switches and a storage element.
5. The converter of claim 1, comprising two (2) quadrants and nine (9) output levels.
6. The converter of claim 5, comprising four (4) cells connected in series, and wherein each cell represents a two-quadrant H-bridge converter.
7. The converter of claim 6, wherein each cell of the plurality of cells comprises two (2) bidirectional switches, two (2) diodes, and a storage element.
8. The converter of claim 1, wherein each bidirectional switch comprises IGBT or MOSFET with freewheeling diode.
9. The converter of claim 1, wherein the isolated converter is one of an isolated AC/DC or an isolated DC/AC converter.

10. The converter of claim 1, wherein electrical power is transferrable from each cell of the plurality of cells to the load, and wherein electrical power is transferrable from the load to each cell of the plurality of cells in the case of a reactive or regenerative load.

11. The converter of claims 1-10, wherein the load is one of a single phase or multiple-phased resistive and inductive load, or pure reactive load, or any type of regenerative load.

12. The converter of claim 11, wherein the control system is further configured to cause the transfer of electrical power from the energy storage elements of the power cells to the load.

13. The converter of claim 12, wherein the control system is further configured to recover energy back to the storage elements when the load is a reactive or regenerative load.

14. The converter of claim 12, wherein the control system is further configured to balance voltages on the energy storage elements.

15. The converter of claim 14, wherein the balance of voltages includes selection of the energy storage elements with the minimum and maximum voltages, and determination of whether to extract energy from a selected energy storage element.

16. The converter of claim 15, wherein the balance of voltages includes determination of whether to extract energy from a selected energy storage element into the load or inject energy from the load into the selected energy storage element when the load is a reactive or regenerative load.

17. The converter of claim 12, wherein the control system is further configured to minimize commutation of the switching elements through zero switching rotation.

18. The converter of claim 1, wherein the storage element is a capacitor.

19. The converter of claims 1-18, wherein the control system including one or more processors coupled to a non-transitory memory comprising a plurality of instructions that when executed causes the one or more processors to control one or more of a shape and a level of current in the load.

20. The converter of claim 19, wherein the plurality of instructions when executed causes the one or more processors to control an output voltage level of the converter as a function of the level of current in the load, a reference current and a current error equal to the difference between the level of current in the load and the reference current.

21. The converter of claim 19, wherein the plurality of instructions when executed causes the one or more processors to:

determine a voltage on a storage element for each cell of the plurality of cells;

select a cell of the plurality of cells based on the voltages on the storage elements of the plurality of cells; and

repetitively switch the selected cell to provide a required output voltage level and regulation of output current.

22. The converter of claim 21, wherein the plurality of instructions when executed further causes the one or more processors to extract energy from the selected cell into a reactive or regenerative load.

23. The converter of claim 21, wherein the plurality of instructions when executed further the one or more processors to extract energy from a reactive or regenerative load into the selected cell.

24. The converter of claim 19, wherein the plurality of instructions when executed causes the one or more processors to:

provide a zero-voltage for a first positive/negative operational level of the cell using a first subset of the plurality of bidirectional switches; and

provide a zero voltage for a second positive/negative operational level of the cell using a second subset of the plurality of bidirectional switches;

wherein the first subset is different from the second subset, and wherein the second positive/negative operational level of the cell is directly subsequent the first positive/negative operational level of the cell.

25. The converter of claim 19, wherein the plurality of instructions when executed causes the one or more processors to:

subtract a real feedback current signal I_{REAL} from a reference current signal I_{REF} to produce a current error signal I_{ERROR} ;

input the current error signal I_{ERROR} into each hysteresis block of a plurality of hysteresis blocks, wherein each hysteresis block of the plurality of hysteresis blocks has a different setting of high boundary (HB) threshold and low boundary (LB) threshold than the other hysteresis blocks of the plurality of hysteresis blocks;

for each hysteresis block of the plurality of hysteresis blocks,

set an output value of the hysteresis block to "1" when I_{ERROR} reaches the high boundary (HB) threshold of the hysteresis block;

maintain the output value of the hysteresis block at "1" until I_{ERROR} reaches the low boundary (LB) threshold of the hysteresis block; and

set the output value of the hysteresis block to "0" when I_{ERROR} reaches the low boundary (LB) threshold of the hysteresis block;

sum the output values of all of the hysteresis blocks of the plurality of hysteresis blocks to produce a total state value;

select the required output voltage level from a lookup table as a function of the total state value.

26. The converter of claim 25, wherein the selection of the required output voltage is a function of the total state value and a sign of current derivative di/dt .

27. The converter of claim 26, wherein the current derivative is one of real or reference.

28. The converter of claim 26, wherein the sign of the current derivative di/dt is determined as positive at a moment of time when the total state value reaches a value of six (6).

29. The converter of claim 26, wherein the sign of the current derivative di/dt is determined as negative at a moment of time when the total state value reaches a value of one (1).

30. A method of balancing voltages on a plurality of cells of a multi-quadrant multi-level cascaded converter, comprising:

for each cell of the plurality of cells, determining a voltage on a storage element of the cell;

selecting, based on the voltages on the storage elements of the plurality of cells, a selected cell of the plurality of cells; and

repetitively switching the selected cell to provide a required output voltage level and regulation of output current.

31. The method of claim 30, further comprising extracting energy from the selected cell into a reactive or regenerative load.

32. The method of claim 30, further comprising extracting energy from a reactive or regenerative load into the selected cell.

33. The method of claim 30, wherein the storage elements are capacitors.

34. A method of distributing energy among a plurality of bidirectional switches of a cell of a plurality of cells in a multi-quadrant multi-level cascaded converter, comprising:

using a first subset of the plurality of bidirectional switches to provide a zero-voltage for a first positive/negative operational level of the cell; and

using a second subset of the plurality of bidirectional switches to provide a zero voltage for a second positive/negative operational level of the cell;

wherein the first subset is different from the second subset, and wherein the second positive/negative operational level of the cell is directly subsequent the first positive/negative operational level of the cell.

35. A method of selecting a required output voltage level of a multi-quadrant multi-level cascaded converter, comprising:

subtracting a real feedback current signal I_{REAL} from a reference current signal I_{REF} to produce a current error signal I_{ERROR} ;

inputting the current error signal I_{ERROR} into each hysteresis block of a plurality of hysteresis blocks, wherein each hysteresis block of the plurality of hysteresis blocks has a different setting of high boundary (HB) threshold and low boundary (LB) threshold than the other hysteresis blocks of the plurality of hysteresis blocks;

for each hysteresis block of the plurality of hysteresis blocks,

 when I_{ERROR} reaches the high boundary (HB) threshold of the hysteresis block, setting an output value of the hysteresis block to “1”;

 maintaining the output value of the hysteresis block at “1” until I_{ERROR} reaches the low boundary (LB) threshold of the hysteresis block; and

 when I_{ERROR} reaches the low boundary (LB) threshold of the hysteresis block, setting the output value of the hysteresis block to “0”;

summing the output values of all of the hysteresis blocks of the plurality of hysteresis blocks to produce a total state value;

selecting, from a lookup table based upon the total state value, the required output voltage level.

36. The method of claim 35, selecting the required output voltage is based upon the total state value and a sign of current derivative di/dt .

37. The method of claim 36, wherein the current derivative is one of real or reference.

36. The method of claim 36, wherein the sign of the current derivative di/dt is determined as positive at a moment of time when the total state value reaches a value of six (6).

39. The method of claim 36, wherein the sign of the current derivative di/dt is determined as negative at a moment of time when the total state value reaches a value of one (1).