CLAIMS

What is claimed is:

1. An electric vehicle comprising:

a chassis,

three or more wheels operably coupled to the chassis,

one or more electric motors operably coupled to the three or more wheels,

one or more intelligent modular battery packs operably coupled to the one or more motors, and

a control system operably coupled to the one or more battery packs and the one or more motors.

2. The electric vehicle of claim 1 wherein the chassis is drivetrain-less.

3. The electric vehicle of claim 1 wherein the one or more motors are in-wheel motors.

4. The electric vehicle of claim 1 wherein the one or more intelligent modular battery packs having a cascaded architecture.

5. The electric vehicle of claim 4 wherein the battery packs comprise a plurality of interconnected intelligent battery modules.

6. The electric vehicle of claim 5 wherein the battery modules comprise an integrated combination of a networked low voltage converter/controller with peer-to-peer communication capability, embedded ultra-capacitor, battery management system and serially connected set of individual cells.

7. The electric vehicle of claim 1 wherein the battery packs comprise a neural network comprising a plurality of inter-connected intelligent battery modules.

~~8. The electric vehicle of claim 5 wherein the battery modules comprise an integrated combination of a battery with a BMS, a supercapacitor module, and an output converter.~~

~~9. The electric vehicle of claim 8 wherein the supercapacitor module includes a bidirectional DC-DC converter and a supercapacitor bank.~~

~~10. The electric vehicle of claim 8 wherein the output converter comprises a four-quadrant H-bridge.~~

~~11. The electric vehicle of claim 1 wherein the control system comprises a bi-directional multilevel controller.~~

~~12. The electric vehicle of claim 11, wherein the bi-directional multilevel controller is a bi-directional multilevel hysteresis controller.~~

~~13. The electric vehicle of claim 11, wherein the bi-directional multilevel controller is combined with temperature sensors and networking interface logic.~~

~~14. The electric vehicle of claims 11-13, wherein the control system is configured to balance battery utilization through individual switching of modules based on module age, thermal condition and performance characteristics.~~

~~15. The electric vehicle of claims 1-14, wherein the battery packs are switchable to a rectifier/charger operation.~~

~~16. AN INTELLIGENT~~

1. A modular battery pack system controllable to supply power to a motor load of an electric vehicle (EV), the modular battery pack system comprising:

a plurality of converter modules arranged in at least three cascades, each cascade comprising at least two converter modules coupled together to output a single phase AC voltage

signal comprising a ~~cascaded architecture comprising a plurality of inter-connected intelligent battery modules.~~superposition of pulse width modulated (PWM) output voltages from each of the at least two converter modules, wherein the at least three cascades together output AC voltage signals of at least three different phases, and wherein each of the plurality of converter modules comprises:

~~17. The intelligent modular battery pack of claim 16 wherein the battery modules comprise an integrated combination of a networked low-voltage converter/controller with peer-to-peer communication capability, embedded ultra-capacitor, battery management system and serially connected set of individual cells.~~

a primary energy source coupled between a first node and a common node, wherein the primary energy source is a battery and wherein a ~~18. The intelligent modular battery pack of claim 16 wherein the inter-connected intelligent battery modules comprise a neural network.~~

~~19. The intelligent modular battery pack of claim 16 wherein the battery modules comprise an integrated combination of a battery with a BMS, a supercapacitor module, and an output converter.~~

~~20. The intelligent modular battery pack of claim 19 wherein the supercapacitor module includes a bidirectional DC-DC converter and a supercapacitor bank.~~

~~21. The intelligent modular battery pack of claim 19 wherein the output converter comprises a four-quadrant H-bridge.~~

~~22. An intelligent battery module comprising an integrated low-voltage converter/controller with peer-to-peer communication capability, an embedded ultra-capacitor, a battery management system, and a plurality of serially connected set of individual cells.~~

voltage between the first and common nodes is V_{DC};

a secondary energy source coupled between an inductor and the common node;

switch circuitry comprising a first plurality of switches controllable to selectively couple the secondary energy source through the inductor to either the first node or the

common node, and a second plurality of switches controllable to selectively output one of three voltages from the module, wherein the three voltages are $+V_{DC}$, zero, and V_{DC};

a capacitor coupled between the first node and the common node and adapted to receive and store energy from the inductor; and

a local control device configured to output switch signals to the first and second plurality of switches and configured to output state of charge (SOC) information about the battery; and

a master control device configured to use SOC information received from each local control device to generate and output control information to each of the local control devices to balance utilization of each battery across the plurality of converter modules.

2. The modular battery pack system of claim 1, wherein each battery comprises a serial connection of battery cells.

3. The modular battery pack system of claim 1, wherein each secondary energy source is a supercapacitor or an ultracapacitor.

4. The modular battery pack system of claim 1, wherein each switch of the first plurality of switches is a transistor with a parallel diode.

5. The modular battery pack system of claim 1, wherein, for each converter module of the plurality of converter modules, the switch circuitry is controllable to supply power from the secondary energy source to supplement power provided by the battery during acceleration of the EV.

6. The modular battery pack system of claim 1, wherein, for each converter module of the plurality of converter modules, the switch circuitry is controllable to charge the battery during regenerative braking of the EV.

7. The modular battery pack system of claim 1, wherein, for each converter module of the plurality of converter modules, the switch circuitry is controllable to charge the secondary energy source during regenerative braking of the EV.

8. The modular battery pack system of claim 1, wherein, for each converter module of the plurality of converter modules, the switch circuitry is controllable to inject excess current to charge the secondary energy source when a charge current produced during regenerative braking of the EV exceeds a battery limit.

9. The modular battery pack system of claim 1, wherein, for each converter module of the plurality of converter modules, the switch circuitry is controllable to decouple both the battery and secondary energy source from the motor load of the EV.

~~23. The intelligent battery module of claim 22, wherein the converter/controller comprises a four-quadrant H-bridge.~~

~~24. An intelligent battery module comprising~~
~~a battery with an integrated BMS,~~
~~a supercapacitor module operably coupled to the battery, and~~
~~an output converter operably coupled to the battery and the supercapacitor module.~~

~~25. The intelligent battery module of claim 24 wherein the supercapacitor module includes a bidirectional DC-DC converter and a supercapacitor bank.~~

~~26. The intelligent battery module of claim 24 wherein the output converter~~ 10. ~~comprises a four-quadrant H-bridge.~~ The modular battery pack system of claim 1, wherein, for each converter module of the plurality of converter modules, the switch circuitry is controllable to use current from the secondary energy source to actively filter a second order harmonic in current from the battery.

11. The modular battery pack system of claim 1, wherein the master control device is configured to generate and output control information comprising switch signals to each of the local control devices.

12. The modular battery pack system of claim 1, wherein, for each converter module of the plurality of converter modules, the local control device is configured to generate and output switch signals for the first plurality of switches.

13. The modular battery pack system of claim 1, wherein each converter module of the plurality of converter modules comprises temperature, voltage and current sensors, and the local control device is configured to process signals from the temperature, voltage and current sensors of the converter module.

14. The modular battery pack system of claim 1, wherein each cascade comprises S converter modules, wherein S is two or more, the system configured to:

generate, for each cascade, at least one reference signal and at least S carrier signals, wherein each of the at least S carrier signals has a different phase;

generate, for each cascade, at least 2S pulse width modulated (PWM) switching signals by use of the at least one reference signal and the at least S carrier signals; and

control the second plurality of switches of the S converter modules of each cascade with the PWM switching signals such that each cascade outputs the single phase AC voltage signal comprising the superposition of output voltages from each of the S converter modules of the cascade.

15. A modular battery pack system controllable to supply power to a motor load of an electric vehicle (EV), the modular battery pack system comprising:

a plurality of converter modules arranged in at least three cascades, each cascade comprising at least two converter modules coupled together to output a single phase AC voltage signal comprising a superposition of pulse width modulated (PWM) output voltages from each of the at least two converter modules, wherein the at least three cascades together output AC

voltage signals of at least three different phases, and wherein each of the plurality of converter modules comprises:

a primary energy source coupled between a first node and a common node, wherein the primary energy source is a battery;

a secondary energy source coupled between an inductor and the common node;

switch circuitry comprising a first plurality of switches controllable to selectively couple the secondary energy source through the inductor to either the first node or the common node, and a second plurality of switches controllable to selectively output three voltages from the module,

wherein the switch circuitry is controllable to supply power from the secondary energy source to supplement power provided by the battery during acceleration of the EV and to charge the battery and the secondary energy source during regenerative braking of the EV;

a capacitor coupled between the first node and the common node and adapted to receive and store energy from the inductor; and

a local control device configured to output switch signals to the first and second plurality of switches and configured to output a sensed operating parameter about the converter module; and

a master control device configured to use the sensed operating parameter received from each local control device to generate and output control information to each of the local control devices to balance utilization of each battery across the plurality of converter modules.

16. The modular battery pack system of claim 15, wherein the sensed operating parameter is a state of charge (SOC) of the battery, a voltage of the battery, a current of the battery, or a temperature.

17. The modular battery pack system of claim 15, wherein each battery comprises a serial connection of battery cells.

18. The modular battery pack system of claim 15, wherein each secondary energy source is a supercapacitor or an ultracapacitor.

19. The modular battery pack system of claim 15, wherein each switch of the first plurality of switches is a transistor with a parallel diode.

20. The modular battery pack system of claim 15, wherein, for each converter module of the plurality of converter modules, the switch circuitry is controllable to inject excess current to charge the secondary energy source when a charge current produced during regenerative braking of the EV exceeds a battery limit.

21. The modular battery pack system of claim 15, wherein, for each converter module of the plurality of converter modules, the switch circuitry is controllable to decouple both the battery and secondary energy source from the motor load of the EV.

22. The modular battery pack system of claim 15, wherein, for each converter module of the plurality of converter modules, the switch circuitry is controllable to use current from the secondary energy source to actively filter a second order harmonic in current from the battery.

23. The modular battery pack system of claim 15, wherein the master control device is configured to generate and output control information comprising switch signals to each of the local control devices.

24. The modular battery pack system of claim 15, wherein, for each converter module of the plurality of converter modules, the local control device is configured to generate and output switch signals for the first plurality of switches.

25. The modular battery pack system of claim 15, wherein each converter module of the plurality of converter modules comprises temperature, voltage and current sensors, and the local control device is configured to process signals from the temperature, voltage and current sensors of the converter module.

26. The modular battery pack system of claim 15, wherein each cascade comprises S converter modules, wherein S is two or more, the system configured to:

generate, for each cascade, at least one reference signal and at least S carrier signals, wherein each of the at least S carrier signals has a different phase;

generate, for each cascade, at least 2S pulse width modulated (PWM) switching signals by use of the at least one reference signal and the at least S carrier signals; and

control the second plurality of switches of the S converter modules of each cascade with the PWM switching signals such that each cascade outputs the single phase AC voltage signal comprising the superposition of output voltages from each of the S converter modules of the cascade.

27. A method of generating power for a load using a modular battery pack system that comprises a plurality of converter modules arranged in at least three cascades, each cascade comprising S converter modules coupled in series wherein S is two or more, wherein the at least three cascades together output AC voltage signals of at least three different phases, and wherein each converter module comprises a battery and a plurality of switches controllable to selectively output voltages from the module, the method comprising:

sensing operating parameters about the batteries of the plurality of converter modules;

generating, for each cascade, at least one reference signal;

generating, for each cascade, at least S carrier signals wherein each of the at least S carrier signals has a different phase;

generating, for each cascade, at least 2S pulse width modulated (PWM) switching signals using the at least one reference signal and the at least S carrier signals; and

controlling the plurality of switches of the S converter modules of each cascade with the PWM switching signals such that each cascade outputs a single phase AC voltage signal comprising a superposition of output voltages from each of the S converter modules of the cascade,

wherein control of the plurality of switches of the S converter modules of each cascade with the generated PWM switching signals is for utilization balancing of each battery across the plurality of converter modules.

28. The method of claim 27, wherein controlling the plurality of switches of the S converter modules of each cascade with the PWM switching signals comprises:

controlling the plurality of switches of a first converter module of a first cascade to selectively output one of three output voltages, wherein the three output voltages are +V, 0, and -V.

29. The method of claim 27, wherein the at least S carrier signals each have a different phase separated by 360°/2S.

30. The method of claim 27, wherein a first reference signal Vref and a second reference signal -Vref are generated for each cascade, and wherein the at least S carrier signals are triangular carrier signals.

31. The method of claim 27, wherein the operating parameters comprise states of charge (SOC) of the batteries, and wherein control of the plurality of switches of the S converter modules of each cascade with the generated PWM switching signals is for SOC balancing of each battery across the plurality of converter modules.

32. The method of claim 31, further comprising comparing a state of charge (SOC) for a battery to a total state of charge (SOC) for SOC balancing.

33. The method of claim 27, wherein the operating parameters comprise states of charge (SOC) and temperatures of the batteries, and wherein control of the plurality of switches of the S converter modules of each cascade with the generated PWM switching signals is for SOC balancing and thermal management of each battery across the plurality of converter modules.

34. The method of claim 27, wherein generation of the PWM switching signals and control of the plurality of switches of the S converter modules of each cascade with the generated PWM switching signals balances state of charge (SOC) and temperature of each battery across the plurality of converter modules.

35. The method of claim 27, further comprising controlling a modulation index of each of the S converter modules of each cascade.

36. The method of claim 35, wherein control of the modulation index for a converter module is based on a state of charge (SOC) and capacity of the battery of the converter module.

37. The method of claim 27, wherein the battery of each of the plurality of converter modules is a primary energy source, and wherein each of the plurality of converter modules comprises a secondary energy source.

38. The method of claim 37, further comprising actively filtering a second order harmonic in a battery output of each converter module with the secondary energy source.

39. The method of claim 27, wherein the load is a motor of a vehicle, the battery of each of the plurality of converter modules is a primary energy source, and each of the plurality of converter modules comprises a secondary energy source.

40. The method of claim 39, further comprising supplying power from each secondary energy source to supplement power supplied by each battery during acceleration of the vehicle.

41. The method of claim 39, further comprising charging each battery and secondary energy source with regenerative braking current.

42. The method of claim 39, further comprising, when a charge current produced during regenerative braking exceeds a battery limit, injecting at least an excess charge current to the secondary energy source.

43. The method of claim 39, wherein each secondary energy source is a supercapacitor or an ultracapacitor.

44. The method of claim 27, wherein the load is an in-wheel motor of a vehicle.