CLAIMS

1. A modular energy system controllable to supply power to a load, comprising:

a plurality of modules connected together to output an AC voltage signal comprising a superposition of first output voltages from each module,

wherein each module comprises:

an energy source;

a first converter connected to the energy source and configured to generate the first output voltage at a first port of the module; and

a second converter connected between a second port of the module and the energy source, wherein the second converter is configured to receive ~~a charge~~an input signal ~~at the second port~~ and convert the ~~charge~~input signal into a second output voltage ~~to charge the energy source~~.

2. The system of claim 1, wherein the first converter comprises a plurality of switches.

3. The system of claim 2, wherein the plurality of switches are configured as a full bridge converter.

4. The system of claim 1, wherein the second converter is a DC-DC converter comprising a transformer configured to isolate the energy source and the first converter from the second port.

5. The system of claim 4, wherein the second converter comprises a DC-AC converter connected between the second port and the transformer.

6. The system of claim 5, wherein the second converter comprises a diode rectifier connected between the transformer and the energy source.

7. The system of claim 4, wherein the second converter comprises an AC-DC converter connected between the transformer and the energy source.

8. The system of claim 7, wherein the AC-DC converter is configured as a full bridge converter or a push-pull converter.

9. The system of claim 4, wherein the second converter is a unidirectional converter that conducts electricity from the second port to the energy source.

10. The system of claim 4, wherein the second converter is a bidirectional converter that conducts electricity between the second port and the energy source.

11. The system of claim 1, wherein the plurality of modules are serially connected as an array and are connected to receive a total charge source voltage such that a voltage of the charge signal applied to the second port of each module is divided down from the total charge source voltage.

12. The system of any of claims 1-11, wherein the energy source is a first energy source, and wherein each module comprises a second energy source.

13. The system of claim 12, wherein the second energy source is connected to the first converter by an inductor.

14. The system of claim 12, wherein the first energy source is a lithium ion battery of a first type and the second energy source is a lithium ion battery of a second type, wherein the first and second types are different.

15. The system of claim 12, wherein the first energy source is a battery and the second energy source is a high energy density (HED) capacitor.

16. The system of any of claims 1-11, wherein each module further comprises an energy buffer connected in parallel with the energy source.

17. The system of claim 16, wherein the energy buffer is a capacitor.

18. The system of any of claims 1-17, further comprising a control system configured to control switching of the first and second converters.

19. The system of claim 18, wherein the control system comprises a plurality of local control devices associated with the plurality of modules, and a master control device communicatively coupled with the plurality of local control devices.

20. The system of claim 18, wherein the control system is configured to control switching of the second converter of each module to exchange energy between energy sources of the modules.

~~21.~~21. The system of claim 1, wherein the input signal is a charge signal and the second converter is configured to receive the charge signal at the second port and convert the charge signal into the second output voltage to charge the energy source.

22. The system of claim 1, wherein the input signal is an output voltage of the energy source and the second converter is configured to convert the output voltage of the energy source to a supply voltage for an auxiliary converter.

23. A modular energy system controllable to supply power to a load, comprising:

a first array comprising a first plurality of modules connected together to output a first AC voltage signal comprising a superposition of output voltages from the first plurality of modules; and

a second array comprising a second plurality of modules connected together to output a second AC voltage signal comprising a superposition of output voltages from the second plurality of modules,

wherein each module of the first plurality and second plurality of modules comprises:

an energy source;

a first converter connected to the energy source and configured to generate the output voltage at a first port of the module; and

a second converter connected to a second port of the module and the energy source, wherein the second converter is configured to receive ~~a charge~~an input signal ~~at the second port~~ and convert the ~~charge~~input signal into ~~a charge voltage to charge the energy source~~an output signal.

~~22~~24. The system of claim ~~21~~23, further comprising a first interconnection module coupled with the first array and a second interconnection module coupled with the second array, wherein the first and second interconnection modules each comprise:

a first port and a second port;

an energy source;

a first converter connected to the energy source and configured to generate an output voltage at the first port; and

a second converter connected to the second port and the energy source, wherein the second converter is configured to receive a charge signal at the second port and convert the charge signal into a charge voltage to charge the energy source.

~~23. The system of claim 22, wherein the energy sources of the first and second interconnection modules are connected in parallel.~~

~~24. The system of any of claims 22-23, wherein the first interconnection module is configured to supply power for an auxiliary load.~~

25. The system of claim 24, wherein the first interconnection module comprises a third port configured to connect the energy source of the first interconnection module to an auxiliary load.

26. The system of claim 24, ~~wherein the first interconnection module comprises a third port configured to connect the energy source of the first interconnection module through switch circuitry and an inductor of the first interconnection module to an auxiliary load external to the first interconnection module.~~

~~27. The system of any of claims 22-26,~~ further comprising a control system configured to control the first converter of each of the first and second interconnection modules to balance energy between the first and second arrays.

~~28. The system of any of claims 22-26, further comprising a control system configured to control the first converter of each of the first and second interconnection modules to balance energy between the first and second arrays.~~

~~29~~27. The system of claim ~~21, wherein the first converter comprises a plurality of switches.~~

~~30. The system of claim 29, wherein the plurality of switches are configured as a full bridge converter.~~

~~31. The system of claim 21~~24, wherein the second converter is a DC-DC converter comprising a transformer configured to isolate the energy source and the first converter from the second port.

~~32. The system of claim 31, wherein the second converter comprises a DC-AC converter connected between the second port and the transformer.~~

~~33. The system of claim 32, wherein the second converter comprises a diode rectifier connected between the transformer and the energy source.~~

~~34. The system of claim 31, wherein the second converter comprises an AC-DC converter connected between the transformer and the energy source.~~

~~35. The system of claim 34, wherein the AC-DC converter is configured as a full bridge converter or a push-pull converter.~~

~~36. The system of claim 31, wherein the second converter is a unidirectional converter that conducts electricity from the second port to the energy source.~~

~~37. The system of claim 31, wherein the second converter is a bidirectional converter that conducts electricity between the second port and the energy source.~~

~~38. The system of claim 21, wherein the first plurality of modules are serially connected in the first array and are connected to receive a total charge source voltage such that a voltage of the charge signal applied to the second port of each module of the first array is divided down from the total charge source voltage.~~

~~39. The system of any of claims 21-38, wherein the energy source is a first energy source, and wherein each module comprises a second energy source.~~

~~40. The system of claim 39, wherein the second energy source is connected to the first converter by an inductor.~~

~~41. The system of claim 39, wherein the first energy source is a lithium ion battery of a first type and the second energy source is a lithium ion battery of a second type, wherein the first and second types are different.~~

~~42. The system of claim 39, wherein the first energy source is a battery and the second energy source is a high energy density (HED) capacitor.~~

~~43. The system of any of claims 21-38, wherein each module of the first plurality of modules, each module of the second plurality of modules, the first interconnection module, and~~

the second interconnection module further comprises an energy buffer connected in parallel with the energy source.

44. The system of claim 43, wherein the energy buffer is a capacitor.

45. The system of any of claims 21-44, further comprising a control system configured to control switching of the first and second converters.

46. The system of claim 45, wherein the control system comprises a plurality of local control devices associated with the plurality of modules, and a master control device communicatively coupled with the plurality of local control devices.

47. The system of claim 45, wherein the control system is configured to control switching of the second converter of each module to exchange energy between energy sources of the modules.

4828. A modular energy system controllable to supply power to loads of an electric vehiclea load, comprising:

a first plurality of modules connected together in first, second, and third arrays, each array configured to output an AC voltage signal comprising a superposition of first output voltages from the modules of that array; and

a second plurality of modules connected together in a fourth array configured to output an AC voltage signal comprising a superposition of output voltages from the second plurality of modules,

each module, wherein the first plurality of modules are configured to provide three-phase power to a first auxiliary load of the electric vehicle, and

wherein the second plurality of modules are configured to provide single phase power to a second auxiliary load of the electric vehicle.

49. The modular energy system of claim 48, further comprising a plurality of interconnection modules connected to the first, second, third, and fourth arrays.

~~50. The modular energy system of claim 49, wherein a first interconnection module of the plurality of interconnection modules is configured to provide DC power to a third auxiliary load of the electric vehicle.~~

~~51. The system of claim 50, wherein the first interconnection~~each module comprises an energy source~~ and is configured to connect the energy source to the third auxiliary load.~~

~~52. The system of claim 50, wherein the first interconnection module comprises an energy source and is configured to connect the energy source through switch circuitry and an inductor of the first interconnection module to the third auxiliary load.~~

~~53. The modular energy system of any of claims 48-50, wherein all of the modules individually comprise:~~

~~an energy source;~~

, a first converter connected to the energy source and configured to generate the first output voltage at a first port of the module, and a second converter connected between a second port of the module and the energy source; and

~~a second converter connected to a second port of the module and the energy source, wherein the second converter is configured to receive a charge signal at the second port and convert the charge signal into a charge voltage to charge the energy source.~~

~~54. The system of claim 53, further comprising~~ a control system configured to control the first converter and the second converter of each ~~of the plurality of interconnection modules to balance energy between the first, second, third, and fourth arrays~~module.

~~55. The system of claim 53, wherein modules of the first array are serially connected to receive a total charge source voltage such that a voltage of the charge signal applied to the second port of each module of the first array is divided down from the total charge source voltage.~~

56. The system of claim 53, wherein the first array, second array, and third array are connected in parallel to receive a total charge source voltage such that a voltage of the charge signal applied to the second port of each module of each array is divided down from the total charge source voltage.

57. The system of any of claims 48-56, wherein every module further comprises an energy buffer.

58. The system of claim 57, wherein the energy buffer is a capacitor.

59. The system of any of claims 48-58, further comprising a control system configured to control each of the modules.

60. A rail-based electric vehicle, comprising:

a modular energy system controllable to supply power to a load of the rail-based electric vehicle, wherein the modular energy system is configured in accordance with any of claims 1-47.

61. The rail-based electric vehicle of claim 60, configured as an electric train or an electric tram.

62. The rail-based electric vehicle of claim 60, configured to intermittently connect to a charge source while in motion.

63. The rail-based electric vehicle of claim 62, wherein the charge source is a catenary.

64. The rail-based electric vehicle of any of claims 60-63, wherein the load is an electric motor.

65. A rail-based electric vehicle, comprising:

~~a modular energy system controllable to supply power to loads of the rail-based electric vehicle, wherein the modular energy system is configured in accordance with any of claims 48-59.~~

~~66. The rail-based electric vehicle of claim 65, configured as an electric train or an electric tram.~~

~~67. The rail-based electric vehicle of claim 65, configured to intermittently connect to a charge source while in motion.~~

~~68. The rail-based electric vehicle of claim 67, wherein the charge source is a catenary.~~

~~69. An electric vehicle, comprising:~~

~~a first modular energy system controllable to supply power to a load of the rail-based electric vehicle, wherein the first modular energy system is configured in accordance with any of claims 1-47, and wherein the load is an electric motor; and~~

~~a second modular energy system controllable to supply power to auxiliary loads of the rail-based electric vehicle, or in the second modular energy system is configured in accordance with any of claims 48-59.~~

~~70. A modular energy system controllable to supply power to a load, comprising:~~

~~a plurality of modules connected together to output an AC voltage signal comprising a superposition of first output voltages from each module, wherein each module comprises an energy source, a first converter connected to the energy source and configured to generate the first output voltage at a first port of the module, and a second converter connected between a second port of the module and the energy source; and~~

~~a control system configured to control the first converter and the second converter of each module.~~

~~71. The system of claim 70, wherein the control system is configured to control the first converter of each module to output the first output voltage according to a pulse width modulation technique.~~

~~72. The system of claim 71, wherein the control system is configured to control the second converter of each module to charge the energy source of the module.~~

~~73. The system of claim 70~~29. The system of claim 28, wherein the control system is configured to control the second converter of each module to charge the energy source of the module and concurrently control the first converter of each module to output the first output voltage.

~~74. The system of claims 72 and 73, wherein at least a subset of modules of the plurality of modules are connected together in cascaded fashion such that the first port of each module in the subset is coupled to a first port of another module in the subset and the second port of each module in the subset is coupled to a second port of another module in the subset.~~

~~75. The system of claim 74, wherein the control system is configured to control the second converter of a first module in the plurality of modules and the second converter of a second module in the plurality of modules to exchange energy between the energy source of the first module and the energy source of the second module.~~

~~76. The system of any of claims 70-75, wherein the second converter of each module of the plurality of modules is a DC-DC converter comprising a transformer configured to isolate the energy source and the first converter from the second port.~~

~~77. The system of claim 76, wherein the second converter of each module of the plurality of modules comprises a DC-AC converter connected between the second port and the transformer.~~

78. The system of claim 77, wherein the second converter of each module of the plurality of modules comprises a diode rectifier connected between the transformer and the energy source.

79. The system of claim 77, wherein the second converter of each module of the plurality of modules comprises an AC-DC converter connected between the transformer and the energy source.

80. The system of claim 79, wherein the AC-DC converter is configured as a full bridge converter or a push-pull converter.

81. The system of any of claims 70-80, wherein the energy source is a first energy source, and wherein each module of the plurality of modules comprises a second energy source coupled with the first converter by way of an inductor.

82. The system of any of claims 70-81, wherein the control system comprises a plurality of local control devices associated with the plurality of modules, and a master control device communicatively coupled with the plurality of local control devices.

83. The system of any of claims 70-82, wherein the first plurality of modules are connected together in first, second, and third arrays, each configured to output an AC voltage signal comprising a superposition of output voltages from the modules of that array.

84. The system of claim 83, further comprising a second plurality of modules connected together in fourth, fifth, and sixth arrays, each configured to output an AC voltage signal comprising a superposition of output voltages from the modules of that array.

85. The system of claim 84, further comprising a third plurality of modules connected together in a seventh array configured to output an AC voltage signal comprising a superposition of output voltages from the third plurality of modules.

~~86. The system of claim 85, wherein the first plurality of modules are configured to provide three-phase power to a motor of the electric vehicle, the second plurality of modules are configured to provide three-phase power to a first auxiliary load of the electric vehicle, and the third plurality of modules are configured to provide single phase power to a second auxiliary load of the electric vehicle.~~

~~87. The modular energy system of claim 86, wherein the control system is configured to control a first converter and a second converter of each module of the second and third pluralities of modules.~~

~~88. The modular energy system of any of claims 70-77 and 79-85~~30. The system of claim 28, further comprising an auxiliary converter coupled to DC lines of the system, the auxiliary converter configured to convert DC power from the DC lines to AC power for an auxiliary load.

~~89. The modular energy system of claim 88, wherein the control system is configured to control the second converter of each module to output a DC voltage from the second port of each module such that the output DC voltages are applied to the DC lines to power the auxiliary converter.~~

~~90. A method of operating a rail-based electric vehicle comprising a modular energy storage system, the method comprising:~~

~~outputting an AC power signal, comprising a plurality of first output voltages from a plurality of modules, to an electric motor of the rail-based electric vehicle, wherein the plurality of modules each comprise an energy source, a first converter coupled with the energy source and configured to output the first output voltage from a first port of the module, and a second converter coupled between the energy source and a second port of the module;~~

~~applying a charge signal to electric vehicle, wherein voltage from the charge signal is applied to the second port of each of the plurality of modules; and~~

~~controlling the second converter of each of the plurality of modules to charge the energy source of each module.~~

~~91. The method of claim 88, wherein the electric vehicle is moving while the charge signal is applied.~~

~~92. The method of claim 88, wherein the modular energy storage system is configured in accordance with any of claims 1-47.~~