

Claims:

1. A system for energy storage, the system comprising:
 - a thermomechanical-electrical conversion subsystem for converting energy formats including:
 - a storage subsystem including a fluid compressor and a first thermal energy exchanger, the storage subsystem for compression of a fluid to generate compressed fluid and thermal energy;
 - a generation subsystem including a power generator and a second thermal energy exchanger, the generation subsystem for generating power from the compressed fluid and the thermal energy;
 - a mechanical and thermal storage unit for storing energy formats including:
 - a pressure vessel for storing the compressed fluid; and
 - a thermal energy storage for storing the thermal energy generated by the fluid compression and for providing the thermal energy to the generation subsystem for generating power.
2. The system of claim 1, wherein the energy formats include any two or more of electricity, thermal energy, and pneumatic energy.
3. The system of claim 1, wherein the energy formats include electricity, thermal energy, and pneumatic energy.
4. The system of claim 1, wherein the compressed fluid is compressed air, and wherein the energy formats include electricity and at least one of thermal energy and pneumatic energy.

5. The system of claim 1, wherein the compressed fluid is compressed air and the compressed air has a pressure between 4 MPa and 70 MPa.
6. The system of claim 1, wherein the pressure vessel is located above ground and is composed of high-strength steel or composite.
7. The system of claim 1, wherein the pressure vessel is located underground in a borehole.
8. The system of claim 7, wherein the borehole includes a first vertical segment housing the pressure vessel and a second vertical segment housing the thermal energy storage.
9. The system of claim 1, wherein the pressure vessel comprises an outer casing enclosing an inner compartment for storing the compressed fluid, and wherein the outer casing is composed of a thermally insulating material.
10. The system of claim 1, wherein the power generator is a microturbine having a capacity range of 250 kW to 25 MW.
11. The system of claim 1, wherein the thermal energy storage comprises at least one of an underground thermal energy storage using ground as storage medium, a phase change storage, a thermo-chemical storage, and a cool thermal energy storage.
12. The system of claim 1, further comprising an end-use device which is fluidly connected to at least one of the thermal and mechanical storage unit and the thermomechanical-electrical conversion subsystem via a fluid transportation subsystem, and wherein the end-use device receives an energy format generated by the system.

13. The system of claim 12, wherein the energy format received by the end-use device is electricity, thermal energy, or pneumatic energy.
14. The system of claim 12, wherein the end-use device is an air treatment unit or a process heating unit, and wherein the energy format received by the end-use device is thermal energy.
15. The system of claim 12, wherein the end-use device is a compressed air-powered device, and wherein the energy format received by the end-use device is pneumatic energy.
16. The system of claim 1, wherein the system operates at a facility having a demand range of 1 MW to 5 MW.
17. The system of claim 1, further comprising a flow transportation subsystem for fluidly connecting the thermomechanical-electrical conversion subsystem and the mechanical and thermal storage unit and transportation of a working fluid therebetween.
18. The system of claim 1, further comprising an energy management unit including a computing device in communication with at least one control device, the energy management unit configured to:

monitor energy format demand data for at least one energy format;

determine a control operation based on the energy format demand data; and

generate control data encoding instructions for performing the control operation, wherein the control data, when received by the at least one control device, causes the control device to perform at least one of:

adjusting a flow of a working fluid between the mechanical and thermal storage unit and the thermomechanical-electrical subsystem; and

adjusting an operating parameter of at least one of the storage subsystem and the generation subsystem.

19. The system of claim 1, wherein the compressed fluid is compressed air, and wherein the system further comprises an electric heater for heating the compressed air after being heated by the second thermal energy exchanger and prior to entering the power generator.

20. The system of claim 19, further comprising:

a first temperature sensor for recording a first temperature measurement of the compressed air prior to entering the second thermal energy exchanger;

a second temperature sensor for recording a second temperature measurement of the compressed air after passing through the second thermal energy exchanger; and

a control unit for:

receiving the first and second temperature measurements from the first and second temperature sensors, respectively;

controlling flow of the thermal energy from the thermal energy storage to the second thermal energy exchanger based on the first temperature measurement; and

controlling a heat output of the electric heater based on the second temperature measurement.

21. An energy management device for controlling storage and delivery of a plurality of energy formats by an energy storage system, the energy storage system including a flow transportation subsystem fluidly connecting a storage subsystem, a generation subsystem, a thermal energy storage, and a pressure vessel, the energy management device comprising:

a memory for storing system optimization rules;

a communication interface configured to:

receive thermal energy stored data from a sensor located at the thermal energy storage, the thermal energy stored data indicating a quantity of thermal energy stored by the thermal energy storage;

receive compressed fluid stored data from a sensor located at the pressure vessel, the compressed fluid stored data indicating a quantity of compressed fluid stored by the pressure vessel; and

receive energy service demand data including a first energy format demand and a second energy format demand; and

a processor configured to:

determine operating parameters for each of the storage subsystem, the generation subsystem, and the flow transportation subsystem based on the thermal energy stored data, compressed fluid stored data, energy service demand data, and system optimization rules;

generate control data encoding instructions for implementing the determined operating parameters;

and wherein the communication interface is further configured to:

transmit the control data to a control device of at least one of the flow transportation subsystem, the storage subsystem, and the generation subsystem.

22. The device of claim 21, wherein the operating parameters include a valve status for a valve of the flow transportation subsystem, and wherein the valve status is either open or closed.
23. The device of claim 21, wherein the generation subsystem includes a power generator, wherein the operating parameters include a power generator status, and wherein the power generator status is either on or off.
24. The device of claim 21, wherein the storage subsystem includes a fluid compressor, wherein the operating parameters include a fluid compressor status, and wherein the fluid compressor status is either on or off.
25. The device of claim 21, wherein the first and second energy formats are any two of electricity, thermal energy, and pneumatic energy.
26. The device of claim 21, wherein the compressed fluid is compressed air, wherein the first energy format is electricity, and wherein the second energy format is thermal energy or pneumatic energy.
27. The device of claim 21, wherein the energy service demand data further includes a third energy format demand.
28. The device of claim 21, wherein the system optimization rules consider at least one of reducing electricity demand and reducing waste energy by the system.
29. A method of controlling an energy storage system operating at a facility, the energy storage system including a flow transportation subsystem fluidly connecting a

storage subsystem, a generation subsystem, a thermal energy storage, and a pressure vessel, the method comprising:

determining operating parameters for each of the storage subsystem, the generation subsystem, and the flow transportation subsystem based on thermal energy stored data indicating a quantity of thermal energy stored by the thermal energy storage, compressed air stored data indicating a quantity of compressed fluid stored by the pressure vessel, power service demand data, second energy service demand data, and system optimization rules;

generating control data encoding instructions for implementing the determined operating parameters; and

transmitting the control data to a control device of each of the flow transportation subsystem, storage subsystem, and generation subsystem.

30. The method of claim 29, wherein the operating parameters include a valve status for a valve of the flow transportation subsystem, and wherein the valve status is either open or closed.
31. The method of claim 29, wherein the generation subsystem includes a power generator, wherein the operating parameters include a power generator status, and wherein the power generator status is either on or off.
32. The method of claim 29, wherein the storage subsystem includes a fluid compressor, wherein the operating parameters include a fluid compressor status, and wherein the fluid compressor status is either on or off.
33. The method of claim 29, wherein the second energy service is either a thermal energy service or a pneumatic energy service.

34. The method of claim 29, further comprising receiving third energy service demand data, wherein the second energy service is a thermal energy service and the third energy service is a pneumatic energy service.
35. The method of claim 29, wherein the system optimization rules consider at least one of reducing electricity demand and reducing waste energy by the system.