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Mechanical-energy storage unit

Abstract

A system may include a flywheel including one or more plates and coupled at a central axis of rotation to a flywheel bearing, the flywheel being adapted to rotate about the central axis. A system may include a flywheel housing providing vertical support to the flywheel bearing. A system may include the flywheel bearing coupling the flywheel to the flywheel housing. A system may include a motor assembly including a motor adapted to convert an input electrical current to rotational momentum by spinning up the flywheel, the motor further being adapted to convert the rotational momentum of the flywheel into an output electrical current. A system may include a flywheel coupling adapted to couple the motor assembly with the flywheel and impart rotational force between the motor and the flywheel.

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Background/Summary

BACKGROUND
(1) The present disclosure relates to mechanical-energy storage units. Implementations relate to flywheel-based mechanical-energy storage units.
(2) Currently, residential electricity customers, as well as electrical utilities, use various sources of electrical energy storage to offset varying electrical power production and use, such as the duck curve describing varying electrical demand on a grid over a day associated with solar or other renewable energy production. The variation in power production and usage has been further exacerbated with the increasing popularity of renewable power sources. These issues cause significant cost and other issues to utilities, such as power outages, brown outs, increased costs, decreased predictability, and other issues.
(3) Commonly, excess or backup power is stored in chemical storage, such as large chemical batteries. Unfortunately, chemical batteries suffer from many issues that make them undesirable at both a residential level and at a utility level. For example, chemical batteries may be very expensive, complex, and require numerous safeguards against fires. Chemical batteries are also ecologically unfriendly, as their production uses toxic chemicals, creates significant greenhouse gases, and results in significant material waste. Furthermore, chemical batteries have short lifespans where the batteries have a limited number of years and recharge cycles before they must be disposed of. For instance, in instances where they are being charged and discharged frequently, such as on a daily basis, they may need to be replaced within just a few short years.
(4) Previous solutions for mechanical energy storage have been overly complex, too large to be implemented at a residential level, not scalable for an electrical utility, lacking safeguards, not adapted for mass production or have faced other issues.
SUMMARY
(5) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly including: a flywheel including one or more plates and coupled at a central axis of rotation to a flywheel bearing, the flywheel being adapted to rotate about the central axis; a flywheel housing providing vertical support to the flywheel bearing; the flywheel bearing coupling the flywheel to the flywheel housing; a motor assembly including a motor adapted to convert an input electrical current to rotational momentum by spinning up the flywheel, the motor further being adapted to convert the rotational momentum of the flywheel into an output electrical current; and a flywheel coupling adapted to couple the motor assembly with the flywheel and impart rotational force between the motor and the flywheel.
(6) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, wherein: the one or more plates include a plurality of metal plates stacked together.
(7) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, wherein: the flywheel includes a plurality of bolts that rotate around the central axis with the plurality of metal plates; and the plurality of bolts adapted to provide compressive force on the plurality of metal plates, the compressive force increasing friction between the plurality of metal plates.
(8) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, wherein: the flywheel housing includes a top structure, a bottom structure, and one or more support members coupling the top structure and the bottom structure together and providing a cavity between the top structure and the bottom structure, the flywheel being located in the cavity when housed by the flywheel housing; the flywheel bearing is coupled with one or more of the top structure and the bottom structure; and the flywheel housing includes one or more bushings coupling the flywheel housing to an external structure.
(9) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, wherein: a rotor of the motor is located at the central axis and coupled with the flywheel coupling to rotate with the flywheel.
(10) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, wherein the flywheel coupling imparting the rotational force between the motor and the flywheel includes: a plurality of magnets arranged circumferentially around the central axis, the flywheel coupling being adapted to allow the flywheel to be mechanically decoupled from the motor while the flywheel coupling is imparting the rotational force.
(11) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, wherein: the flywheel coupling includes a flywheel component coupled with the flywheel and a motor component coupled with the motor, the flywheel component interacting with the motor component using magnetic flux to impart force on the motor component; the flywheel component includes a first plurality of magnets in the flywheel component and located radially relative to the central axis; and the motor component includes a second plurality of magnets in the motor component and located radially relative to the central axis.
(12) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, further including: the first plurality of magnets are polarized in a radial direction outward from the central axis, a magnetic moment of each of the first plurality of magnets being oriented in an alternating direction from an adjacent magnet of the first plurality of magnets; and the second plurality of magnets are polarized in the radial direction outward from the central axis, a magnetic moment of each of the second plurality of magnets being oriented in an alternating direction from an adjacent magnet of the second plurality of magnets.
(13) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, wherein: the flywheel coupling is connected to a control unit, the control unit electronically decoupling the flywheel coupling based on a received electronic signal.
(14) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, wherein: the flywheel coupling is coupled with one or more linear actuators, the one or more linear actuators adapted to decouple the flywheel coupling by lifting a motor component of the flywheel coupling away from a flywheel component of the flywheel coupling.
(15) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, wherein: the one or more linear actuators are further adapted to decouple the flywheel coupling by lifting the motor away from the flywheel component of the flywheel coupling.
(16) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, wherein the flywheel bearing includes: one or more magnets that magnetically levitate the flywheel vertically; and one or more ball bearings that position the flywheel horizontally.
(17) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, wherein: the flywheel housing includes a vacuum chamber, the flywheel being located within the vacuum chamber.
(18) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, wherein: the motor assembly includes a frame coupling the motor to the flywheel housing and adapted to support the motor along the central axis from the flywheel coupling.
(19) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, wherein: the flywheel bearing includes a plurality of adjustment mechanisms adapted to adjust one or more magnets of a magnetic levitation bearing.

(20) In some aspects, the techniques described herein relate to a mechanical-energy storage unit assembly, further including a mechanical-energy storage unit control system coupled with the motor and the flywheel coupling, the mechanical-energy storage unit control system including one or more processors adapted to execute instructions that cause the mechanical-energy storage unit assembly to: receiving a first electronic message instructing the mechanical-energy storage unit assembly to store power; driving the flywheel including spinning up the flywheel using the motor and an input current based on the first electronic message, the flywheel including a plurality of metal plates coupled with a motor using the flywheel coupling; allowing the flywheel to spin for a defined time period; receiving a second electronic message instructing the mechanical-energy storage unit control system to output power; and outputting an electrical current including driving the motor using the flywheel via the flywheel coupling based on the second electronic message.
(21) In some aspects, the techniques described herein relate to a computer-implemented method for controlling a mechanical-energy storage unit including: receiving, by one or more processors, a first electronic message instructing the mechanical-energy storage unit to store power; driving, by the one or more processors, a flywheel of the mechanical-energy storage unit including spinning up the flywheel using a motor and an input current based on the first electronic message, the flywheel including a plurality of metal plates coupled with a motor using a flywheel coupling; allowing, by the one or more processors, the flywheel to spin for a defined time period; receiving, by the one or more processors, a second electronic message instructing the mechanical-energy storage unit to output power; and outputting, by the one or more processors, an electrical current including driving the motor using the flywheel via the flywheel coupling based on the second electronic message.
(22) In some aspects, the techniques described herein relate to a computer-implemented method, further including: receiving, by the one or more processors, a third electronic message instructing the mechanical-energy storage unit to allow the flywheel to spin; and based on the third electronic message, decoupling, by the one or more processors, the motor from the flywheel using the flywheel coupling.
(23) In some aspects, the techniques described herein relate to a computer-implemented method, wherein: decoupling the motor from the flywheel includes actuating a linear actuator to move a motor component of the flywheel coupling away from a flywheel component of the flywheel coupling.
(24) In some aspects, the techniques described herein relate to a system including: a flywheel including one or more plates and coupled at a central axis of rotation to means for allowing the flywheel to rotate about the central axis; a flywheel housing providing support to the means for allowing the flywheel to rotate about the central axis; means for converting an input electrical current to rotational momentum by spinning up the flywheel; means for converting the rotational momentum of the flywheel to an output electrical current; and means for coupling the flywheel to one or more of the means for converting the input electrical current to the rotational momentum and the means for converting the rotational momentum of the flywheel to the output electrical current.
(25) Other implementations of one or more of these aspects or other aspects include corresponding systems, apparatus, and computer programs, configured to perform the various actions and/or store various data described in association with these aspects. These and other implementations, such as various data structures, are encoded on tangible computer storage devices. Numerous additional features may, in some cases, be included in these and various other implementations, as discussed throughout this disclosure. It should be understood that the language used in the present disclosure has been principally selected for readability and instructional purposes, and not to limit the scope of the subject matter disclosed herein.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) This disclosure is illustrated by way of example, and not by way of limitation in the figures of the accompanying drawings in which like reference numerals are used to refer to similar elements.
(2) FIG. **1** includes a block diagram depicting an example energy control platform.
(3) FIG. **2** depicts a block diagram showing example interaction between a utility server, node(s), and EaaS manager.
(4) FIGS. **3**A and **3**B illustrate an example implementation of a mechanical-energy storage unit assembly.
(5) FIGS. **4**A and **4**B illustrate cross sections of an example mechanical-energy storage unit assembly.
(6) FIGS. **5**A and **5**B illustrate perspective views of example flywheels.
(7) FIG. **6**A illustrates an example bolt configuration by which the flywheel disks may be attached together.
(8) FIGS. **6**B and **6**C illustrate examples of a flywheel bearing.
(9) FIG. **6**D illustrates an example flywheel coupling.
(10) FIG. **6**E illustrates an example flywheel housing.
(11) FIG. **7** is a block diagram illustrating an example method for operating a mechanical-energy storage unit assembly to store and retrieve energy.
DETAILED DESCRIPTION
(12) This description includes several improvements over previous solutions, such as those described in reference to the Background. A mechanical-energy storage unit is described herein along with operations to integrate the mechanical-energy storage with an electrical utility provider.
(13) In some implementations, one, two, or more mechanical-energy storage units may be installed at a residence to provide backup power in case of a power outage, to store electricity generated using residential solar panels, or to offset unevenness of power production and usage (e.g., an electrical utility may control the mechanical-energy storage unit at a residence to address the unevenness at the residence, nearby residences, or across the power grid. A mechanical-energy storage unit may be buried next to an electrical panel or placed in a shed outside a residence, placed in a garage or utility room, or stored offsite.
(14) In some implementations, multiple mechanical-energy storage units may coupled together to scale energy backup at a larger facility, such as a business, or by an electrical utility. For instance, many mechanical-energy storage units may be placed at a facility, whether buried or above ground for use by the facility or by an electrical utility provider. The multiple mechanical-energy storage units may include or be coupled to MESU (mechanical energy storage unit) control units that may be communicatively linked to each other or to a central server to control storage and distribution of the stored energy (e.g., by controlling the rotational frequency of a flywheel to keep various flywheels at efficient speeds).
(15) In some implementations, the mechanical-energy storage unit may be based on a flywheel, as described in further detail in reference to the figures herein.
(16) With reference to the figures, reference numbers may be used to refer to components found in any of the figures, regardless of whether those reference numbers are shown in the figure being described. Further, where a reference number includes a letter referring to one of multiple similar components (e.g., component **000***a*, **000***b*, and **000***n*), the reference number may be used without the letter to refer to one or all of the similar components.
(17) The innovative energy technology disclosed in this document provides novel advantages including the ability to integrate modern technology with conventional power infrastructure; enable rapid transition to renewable energy sources; provide backup to the power grid, use the power grid as a backup; store power locally in nodes and regionalized storage clusters of nodes; isolate and minimize the impact of power outages; whether caused by natural disasters, infrastructure failure, or other factors; provide affordable alternatives to expensive and environmentally unfriendly

electrochemical batteries; provide consumers the option to be independent from carbon-based power sources; and decentralize electric power production.
(18) The innovative energy technology disclosed in this document provides novel advantages including the ability to integrate modern technology with conventional power infrastructure; enable rapid transition to renewable energy sources; use the power grid **130** as a backup; store power locally in nodes and regionalized storage clusters **160** of node(s) **140**; isolate and minimize the impact of power outages; whether caused by natural disasters, infrastructure failure, or other factors; provide affordable alternatives to expensive and environmentally unfriendly electrochemical batteries; provide consumers the option to be independent from carbon-based power sources; and decentralize electric power production.
(19) As depicted in FIG. **1**, the innovative energy technology described herein may comprise an energy as a service platform (EaaS platform) **100**. The EaaS platform **100** may include an EaaS manager **110**, user application(s) **172** operable on computing devices accessible to and interactable by user(s) **170** of the EaaS platform **100** and configured to send or receive data to the EaaS manager **110**, regionalized storage clusters **160** comprised of one or more nodes **140**, and the power grid **130** that comprises one or more power facilities **132** that are connected to a power transmission infrastructure **134**.
(20) A node **140** may be comprised of a power consuming entity and at least one MESU **150**. A node **140** may be an entity that either consumers power itself or is coupled to entities that consumer power. In FIG. **1**, a node **140** is depicted as a premises **142**, such as a residential home, but it should be understood that any entity that consumes power is applicable, such as one or more appliances, a commercial structure such as a warehouse or office building, an electronic device or system (whether configured to move or static), a transportation system and/or vehicle, a transportation charging system, a power supply, a power substation, a power substation backup, etc. A regionalized storage cluster includes two or more nodes **140** in a given geographical region. A storage cluster may provide power banking functionality, as discussed further herein. The elements of the node **140** including the MESU(s) **150**, the independent power system **147**, the power grid **130**, and/or any appliances and/or other entities, may be electrically coupled via an electrical system **154** including wiring, junctions, switches, plugs, breakers, transformers, inverters, controllers, and any other suitable electrical componentry.
(21) In the depicted example, a node **140** is equipped with or coupled to power generating technology, such as an independent power system **147** and/or the power grid **130**. The independent power system **147** may comprise power generating technology that is localized and that allows for independent power generation, such as renewable power generating technology. Non-limiting examples include a solar electric system **144** (comprising a solar array, controllers, inverters, etc.), a wind turbine system **146** (comprising turbine(s), controllers, inverters, etc.), and/or other energy sources **148**, such as hydropower, geothermal, nuclear, systems and their constituent components, etc. The power generating technology may additionally or alternatively be conventional carbon-based power generating technology such as the depicted power grid **130**, although for carbon negative or neutral implementation, a greener power generating technology may be preferred.
(22) The node **140** may include or be coupled to an energy storage unit that is capable of storing any excess power that is produced by the power generating technology. In some implementations, the energy storage unit may comprise a mechanical-energy storage unit (MESU) **150**. The MESU **150** includes one or more flywheels **152**A, **152**B . . . **152**N (also simply referred to individually or collectively as **152**). The MESU's **150** convert the electricity received from the power generating technology to kinetic energy by spinning up (increasing the spin rate) of the flywheels **152**.
(23) Each flywheel **152** may be configured to store up to a certain maximum about of energy. By way of non-limiting example, a motor **310** coupled to the flywheel **152** may be configured to spin the flywheel **152** up to between 15,000 rotations per minute (RPM) and 25,000 RPM, such that the flywheel **152** may store between 18 kilowatt hours (kWh) and 28 kWh of electricity. Combined, three stacked flywheels **152** could store between 54 kWh and 84 kWh of power. During hours in which the power generation technology, such as the solar cells, produce less power than what is consumed by the electrical apparatuses (e.g., appliances) of the premises **142**, the motor **310** may be operated as a generator that converts the kinetic (mechanical) energy stored in the flywheel **152** to electricity, thereby pulling power from the flywheel **152** to meet the local power needs of the node **140** (e.g., power the electrical apparatuses of the premises **142**). In this example, advantageously the node **140** may use an average of 15 kWh of power daily and the MESU **150** is capable of powering the node **140** fully for about 4-6 days should the local power generating cease to produce any power.
(24) In another example, as discussed further elsewhere herein, a utility may be integrated with the EaaS manager **110** and its utility management application **122** signal the power management application **111** via the storage cluster APIs **112** that it is experiencing a surge in demand for power, and the power management application **111** may signal a node **140** or cluster of nodes **140** (e.g., storage cluster **160**) to spin off power from the flywheels **152** and provide the energy back to the grid through the transmission infrastructure **134**, which may be connected to the node(s) **140** through connection points (e.g., two or three phase electrical service drops or buried power lines connected to a service panel, which typically includes power meter(s)). Conversely, the utility may be producing excess power and may wish to bank/store the power. The utility management application **122** may signal the power management application **111** via the storage cluster APIs **112** that it needs to store a given amount of power, and the power management application **111** may in turn signal a node **140** or cluster(s) of node(s) **140**, such as one or more regionalized storage clusters **160** to inform them of the storage need, and node(s) **140** in those storage cluster(s) **160** that have excess capacity and are configured to receive power from the grid may receive the power through the transmission infrastructure **134** and store it as mechanical energy in the MESUs for later retrieval. The EaaS platform **100** may charge the utility for the power banking service, as discussed further elsewhere herein.
(25) It should be understood that the RPMs and kWh figures provided in the prior paragraph are meant as non-limiting examples and that the MESU's **150** may be configured with flywheels **152** that are capable of storing more or less power depending on the implementation. For example, the weight of the flywheels **152**, the materials used for the flywheels **152**, the size and configuration of the flywheels **152**, the efficiency of the motor **310** and bearings, and so forth, may all be adjusted based on the use case to provide a desired about of back-up power for the node **140**. By way of further example, a flywheel **152** may be made of steel, aluminum, carbon fiber, titanium, any suitable alloy, and/or any other material that is capable of handling the cycles, vibration, radial and sheer stress and strain, and other conditions to which such a flywheel **152** would be subjected.
(26) The power transmission infrastructure **134** comprises a power network that couples power-consuming entities, such as homes, offices, appliances, etc., to power facilities that generate power from carbon, nuclear, and/or natural sources. The transmission infrastructure **134** may include intervening elements, such as step-up transformers, substations, transmission lines, and so forth, which are interconnected to provide power widely to different geographical regions.
(27) A power utility (also simply referred to as a utility), which may own and operate one or more power facilities and portions of the transmission infrastructure **134**, may operate a utility server configured to execute a utility management application **122**. The utility management application **122** may perform various functions such as load balancing, load managing, and grid energy storage, to manage the supply of electricity based on real-time demand. However, given the limitations of existing grid technologies, power outages, brownouts, and expensive peak power costs are still the norm.
(28) A user may use an instance of a user application **172** executing on a computing device, such as the user's mobile phone or personal computer, to configure and interact with the MESU(s) **150** that they are authorized to control, such as a MESU **150** installed at their home or business, as discussed further elsewhere herein.
(29) As shown in FIG. **1**, the EaaS manager **110**, the utility server **120**, the power facilities **132**, elements of the power grid **130**, the wind turbine

system **146**, the solar electric system **144**, the other sources **148**, the node(s) **140**, the regionalized storage clusters **160**, the user applications **172** and associated computing devices, etc., may be coupled for communication and connected to the network **102** via wireless or wired connections (using network interfaces associated with the computing devices of the foregoing elements). The network **102** may include any number of networks and/or network types. For example, the network **102** may include one or more local area networks (LANs), wide area networks (WANs) (e.g., the Internet), virtual private networks (VPNs), wireless wide area network (WWANs), WiMAX® networks, personal area networks (PANs) (e.g., Bluetooth® communication networks), various combinations thereof, etc. These private and/or public networks may have any number of configurations and/or topologies, and data may be transmitted via the networks using a variety of different communication protocols including, for example, various Internet layer, transport layer, or application layer protocols. For example, data may be transmitted via the networks using TCP/IP, UDP, TCP, HTTP, HTTPS, DASH, RTSP, RTP, RTCP, VOIP, FTP, WS, WAP, SMS, MMS, XMS, IMAP, SMTP, POP, WebDAV, or other known protocols.

(30) The EaaS manager **110**, the utility server **120**, the node(s) **140**, the power facilities, and the user devices may have computer processors, memory, and other elements providing them with non-transitory data processing, storing, and communication capabilities. For example, each of the foregoing elements may include one or more hardware servers, server arrays, storage devices, network interfaces, and/or other computing elements, etc. In some implementations, one or more of the foregoing elements may include one or more virtual servers, which operate in a host server environment. Other variations are also possible and contemplated.

(31) It should be understood that the EaaS platform **100** illustrated in FIG. **1** and the diagram illustrated in FIG. **2** are representative of example systems and that a variety of different system environments and configurations are contemplated and are within the scope of the present disclosure. For example, various acts and/or functionality may be moved between entities (e.g., from a server to a client, or vice versa, between servers, data may be consolidated into a single data store or further segmented into additional data stores, and some implementations may include additional or fewer computing devices, services, and/or networks, and may implement various functionality client or server-side. Further, various entities of the system may be integrated into a single computing device or system or divided into additional computing devices or systems, etc., without departing from the scope of this disclosure.

(32) FIG. **2** depicts a block diagram showing example components of, and the interaction between, the utility server **120**, the node(s) **140**, and the EaaS manager **110**. The utility server includes an instance of the utility management application **122** and an EaaS interface **124**. The EaaS manager **110** includes a power management application **111**, Utility APIs **112**, node APIs **113**, MESU APIs **114**, and a data store **210**. The data store **210** may store and provide access to data related to the EaaS platform **100**, such as cluster data **211**, node data **212**, user data **213**, usage data **214**, utility data **214**, and analytics data **216**.

(33) A node **140** of the EaaS platform may include one or more MESU(s) **150**. A MESU **150** may include an instance of a flywheel controller **254**. The flywheel controller **254** may include a flywheel coupler **255**, a flywheel selector **256**, and flywheel monitor **257**. The MESU hardware **258** may comprise a chassis, one or more flywheels **152**, magnets and/or bearings, a flywheel coupler **255**, and/or a motor-generator **310**. The motor-generator **310** may be coupled to each flywheel **152** via a flywheel coupler **255**. The flywheel coupler **255** may engage and disengage the motor-generator **310** from the flywheel **152**, such that each flywheel **152** may spin freely when disengaged and may be coupled to the motor-generator **310** when engaged such that the motor-generator **310** may increase the speed of the flywheel **152** (spin up the flywheel **152**), or the flywheel **152** may spin the generator to produce power. Each flywheel **152** may be levitated using magnets to minimize the friction caused by the rotation of flywheel **152**. As an example, a maglev unit may be used to suspend and retain the flywheel **152** while spinning.

(34) Additionally, or alternatively, bearings, such as but not limited to ceramic bearings, may be used to support and retain the flywheel **152** while spinning. The chassis may house and support the flywheels **152**. flywheels **152** may be arranged horizontally or vertically. In horizontal orientation, flywheels **152** may have a wheel-like shape and may be stackable one on another in the same chassis, but still configured to spin independently of one another. In such a configuration, the coupler couple to each flywheel **152** independently, or more than one coupler and motor **310** may be used, depending on the implementation. In a vertical orientation, the flywheels **152** may have a roll like shape, and may be positioned parallel to one another in the chassis. In either orientation, in some implementations, the chassis may include a housing that encloses the MESU **150** and provides a vacuum environment in which the components of the MESU **150** may operate. This is advantageous as it may seal out dirt, debris, and corrosion causing elements, and allow for the flywheels **152** and other components to optimally operate.

(35) In some implementations, a node **140** may include one or more MESU(s) **150** and may act as a manager of the MESU(s), may receive and process information from the EaaS manager **110** for the two or more MESU(s) **150**, and may send signals to the MESU(s) **150** (e.g., via the flywheel controller **254** and/or MESU hardware **258**) and receive and process signals from the MESU(s) **150** (e.g., via the flywheel controller **254** and/or MESU hardware **258**), to control the functionality and operations of the MESU(s). In some further implementations, the structure, acts, and/or functionality of the flywheel controller **254** and the node application **240** and their constituent components may be combined, and the node **140** may represent a MESU(s) **150** itself, to which one or more appliances that consume power may be coupled to receive power. Other variations are also possible and contemplated.

(36) The utility management application **122**, the flywheel controller **254**, the node application, the node management application, the utility APIs, the node APIs, and the MESU APIs may each include hardware and/or software executable to provide the acts and functionality disclosed herein.

(37) Specifically, the utility management application **122** may be executable by the utility server to monitor power generation and distribution by one or more power facilities and a transmission infrastructure **134**. The utility management application **122** may receive signals from various entities of the EaaS platform, such as the EaaS manager **110**, the nodes, the transmission infrastructure **134**, other utility management applications associated with other providers, and so forth. The utility management application **122** may communicate via the EaaS interface **124** with the EaaS manager **110** to access the services provided by the EaaS manager **110**. In particular, the EaaS interface **124** may interact with the utility APIs of the EaaS manager **110** to request power banking, request the provision of supplemental power, to provide usage, performance, and/or demand data, and so forth. In some implementations, the EaaS interface **124** may generate and transmit a secure request via the network to the utility APIs. The power management application **111** may receive the request via the utility APIs and process it accordingly.

(38) The power management application **111** may be coupled to the data store **210** to store and retrieve data. The data stored by the data store **210** may be organized and queried using any type of data stored in the data store (e.g., cluster ID, user ID, utility ID, node ID, MESU ID, configuration data, etc.). The data store **210** may include file systems, databases, data tables, documents, or other organized collections of data.

(39) Cluster data **211** may comprise information about a cluster of two or more nodes (e.g., regionalized storage cluster), such as the identity of the node(s) **140**, the storage capacity of the storage cluster **160**, the availability of the storage cluster **160**, the operational health of the storage cluster **160** and/or constituent MESU(s) **150**, the historical performance of the storage cluster **160**, etc.).

(40) Node data **212** may comprise information about a node, such as the number of MESUs installed at the node **140**, the type of node **140**, the operational health of the MESU(s) **150**, any restrictions or operation parameters of the MESU(s) **150**, configuration data for the MESU(s) **150**, identifiers of the MESU(s) **150**, who the MESU(s) **150** belong to, whether the MESU(s) **150** can be used for banking grid power, whether the MESU(s) **150** have been inactivated, and so forth.

(41) User data **213** may comprise information about the user associated with a storage cluster **160**, node **140** or MESU **150**, including user account information, login information, user preferences governing the MESUs (e.g., schedule data, activation/inactivation data, etc.).

(42) Usage data **214** may comprise information about the usage of the clusters and/or MESU(s) **150**, such as spin rates of the flywheels **152**, power output levels, maintenance periods, downtime, inactive periods, third-party use (e.g., use by utilities or neighboring nodes **140**), etc.

(43) Utility data **215** may comprise information about utilities that have partnered with the EaaS platform **100**, such as utility account information, utility capability information, power banking requirements, contractual parameters, performance requirements, power grid **130** specifications, etc.
(44) Analytics data **216** may comprise insights about the EaaS platform **100**, such as local vs. grid power generation, aggregate usage data, aggregate performance data, etc. It should be understood that any other data that would be suitable and applicable to the EaaS platform **100** may be stored and processed by the EaaS manager **110**.
(45) The node application **240** and the flywheel controller **254** may communicate with the EaaS manager **110** via the EaaS interface **242**, which is configured to interact with the node APIs **113** surfaced by the EaaS manager **110**. The node APIs **113** provide methods for accessing data relevant to the node **140** and the MESU(s) **150** associated with the node **140**, and executing various functionality, such as signaling unavailability/availability for banking power, requesting a functional upgrade, such as a higher spin rate for one or more flywheels **152** or deactivating/activating a previously active/inactive flywheel **152**, reporting usage data and/or state information, and so forth.
(46) The flywheel manager **244** of the node application **204** may be configured to communicate with the flywheel controller **254** to provide operational control signals, such as power banking signals, power extraction signals, spin rate adjustment signals, flywheel enablement/disablement signals, and so forth. The energy manager **246** is configured to communicate with the flywheel manager **244** and provides controls signals to the flywheel manager depending on the energy requirements (produce energy for local use, produce energy for utility use, bank local energy, bank utility-provided energy, etc.).
(47) The flywheel coupler **255** may be configured to control the mechanical coupling of the flywheels **152** with the motor-generator **310**, the flywheel selector **256** is configured to select which flywheels **152** to control based on the received control signals, and the flywheel monitor **257** monitors the state of each flywheel **152** for safe operation and performance within defined operational parameters, and can take control of the functionality of the MESU hardware **258** and shut down, slow, suspend, adjust, optimize, or other control the MESU hardware **258** depending on the monitored state.
(48) FIGS. **3**A and **3**B illustrate an example implementation of a mechanical-energy storage unit (MESU) assembly **302** that may use a flywheel **304** to store energy using rotational momentum. FIG. **3**A illustrates a perspective view of an example MESU assembly **302** while FIG. **3**B illustrates a top-down view of the example MESU assembly **302**.
(49) For example, while other implementations are possible and contemplated herein, FIG. **3**A illustrates an example mechanical-energy storage unit (MESU) assembly **302**, according to some implementations, which uses a flywheel **304** to provide energy storage. As illustrated in the example implementation of FIG. **3**A, a MESU assembly **302** may include a flywheel housing **306** providing support to a flywheel bearing **308** that provides support to the flywheel **304**. The flywheel bearing **308** may suspend and allow a flywheel **304** to rotate within a cavity or space in the flywheel housing **306**, for example, about a central axis of rotation. A motor-generator **310** may be coupled or couplable with the flywheel **304** via a flywheel coupler **312** to exert rotational force thereon or receive rotational force therefrom. In some implementations, the MESU assembly **302** may include various other components, such as frames, actuators, electronics, cases, reinforcements, legs **318**, etc., which are described elsewhere herein.
(50) It should be noted that although certain components and configurations are described herein, for example, in reference to FIGS. **3**A-**3**B, other implementations are possible and contemplated herein. For example, a MESU assembly **302** may include fewer, additional, or different components. In some implementations, the MESU assembly **302** may have various other configurations, for example, it may be oriented in various directions, such as where a motor **310** is located below the flywheel **304** or at a side of it, or otherwise.
(51) In some implementations, although not illustrated in the example of FIGS. **3**A-**3**B, the MESU assembly **302** may include other components, such as inverters, wiring, switches, transformers, and/or other power converting or transmission equipment that communicates electrical current from and/or to an external power source, such as an electrical service panel, solar panel system, electrical grid, etc. The equipment may additionally or alternatively couple the MESU assembly **302** to various loads, such as a power grid, electrical service panel, electric vehicle charger, etc.
(52) In some implementations, the MESU assembly **302** may include and/or be coupled with various control equipment, such as a computing device or other control unit that executes various operations, sensors, etc. For example, the MESU assembly **302** may be part of a node **140** and coupled with a flywheel controller **254** and/or node application **240**. For example, the MESU assembly **302** control unit may represent an implementation of the flywheel controller or one of its components. The MESU assembly **302** control unit, etc., as described above may perform various operations respective to the MESU assembly **302**, such as describe in further detail elsewhere herein.
(53) In some implementations, all or a portion of the MESU assembly **302** may be placed within a case or enclosure to provide protection to the MESU assembly **302**, protection from potential flywheel structural failure, and/or a vacuum, which increases flywheel efficiency. For example, a vacuum may be permanent or actively maintained using a vacuum pump. An example enclosure is described in further detail below.
(54) As illustrated in the example of FIGS. **3**A-**3**B, the MESU assembly **302** may include a flywheel **304** including one or more plates coupled at a central axis of rotation to a flywheel bearing **308**, which allows the flywheel **304** to rotate about the central axis. The flywheel **304** may be housed within and supported (e.g., by the flywheel bearing **308**) by the flywheel housing **306**. The MESU assembly **302** may include a motor **310** assembly including a motor **310** adapted to convert an input electrical current to rotational momentum by spinning up the flywheel **304** and/or convert the rotational momentum of the flywheel **304** into an output electrical current. The flywheel **304** may be coupled with the motor **310** using a flywheel coupling **312** that imparts rotational force between the motor **310** and the flywheel **304**.
(55) In some instances, the flywheel **304** may be allowed to spin or freewheel relative to the flywheel housing **306**, for example by allowing a motor **310** to spin freely and/or allow the flywheel coupling **312** to decouple, as described in further detail below. For example, the MESU assembly **302** may include a motor **310** frame **314** that holds the motor **310** and may allow the motor **310** to be moved, depending on the implementation. Additionally, or alternatively, the MESU assembly **302** may include a coupling lifter **316** or other mechanism that electronically couples and/or decouples the flywheel coupling **312** and/or the motor **310** via the motor frame, as described in the examples below.
(56) FIGS. **5**A and **5**B illustrate perspective views of example flywheels **304** according to some implementations. For example, FIG. **5**A illustrates an example flywheel **304** with an example flywheel coupling **312** in a coupled position while FIG. **5**B illustrates the example flywheel **304** with the example flywheel coupling **312** in a closed position. As illustrated, a flywheel **304** may include a massive wheel that rotates about a central axis. In the example of FIGS. **5**A-**5**B, several metal disks may be used and coupled together, for instance using bolts passing through the disks. In some implementations, the flywheel **304** may include disks, rings, or a solid structure, as describe in further detail below.
(57) In the example, ten flywheel disks **510** are shown; however, other quantities and configurations are possible and contemplated herein. The thicknesses, sizes, shapes, and quantities of the disks or plates may vary. For instance, the number of disks can be varied to adjust the amount of energy storage of a mechanical-energy storage unit where additional disks provide additional storage for a minimum in additional cost and complexity without correspondingly increasing a probability of structural failure. The disks **510** may be solid plates, have various perforations (e.g., for bolts or a hub **502**), be circular or other shapes, or have other configurations. Ideally, the disks are symmetrical or otherwise balanced to reduce vibrations when the flywheel **304** is spinning.
(58) Depending on the implementation, the flywheel **304** may be constructed from aluminum, steel, concrete, composite, another material, or a combination thereof. For example, a set of steel flywheel plates or disks coupled together, each of which may be a quarter inch, half inch, inch, or other dimension thick. Other implementations, such as a combination of aluminum and composite (e.g., carbon fiber, etc.) are described in further detail below. In some implementations, the disks may include or be reinforced using other materials, such as Kevlar®, fiberglass, or carbon fiber,

as described elsewhere herein.
(59) The flywheel **304** may have various dimensions that based on material strengths of the flywheel **304**, desired rotational speeds, and/or desired storage capacities. For example, in order to improve manufacturability, decrease danger of material failure, allow the flywheel **304** to be placed at residences or other small-scale applications, the diameter of the flywheel **304** may range between 6 inches to 36 inches, although other sizes are possible. For example, a flywheel **304** may have a diameter of approximately 25 inches and a thickness of 5-12 inches. As noted elsewhere herein, increasing a quantity of disks may increase an energy storage capacity without increasing rotational speeds.
(60) Although many other implementations are possible and contemplated herein, the flywheel **304** have weights ranging from 100-500 pounds, spin at 5,000-25,000 RPM, and have storage capacities of 3-15 kWh, depending on their sizes and materials. For example, by increasing a diameter or quantity of plates, the flywheel energy capacity may be increased to 15-100 kWh. These and other examples provided herein are meant as non-limiting examples and various sizes, materials, configurations, and storage capacities are possible and contemplated.
(61) Various radiuses and rotational velocities may be used to address radial and circumferential stresses. For instance, decreasing diameters may decrease radial stresses but also decrease angular momentum. As material strengths increase, rotational speeds may be increased to correspondingly increase energy storage. As noted elsewhere herein, the RPM of the flywheel **304** may be monitored by a control unit (e.g., a flywheel controller **254**) based on motor **310** speed or one or more sensors, so that the control unit can determine a current energy storage as well as keep the rotation within a target, efficient, or safe speed.
(62) The flywheel **304** may have an aperture through its center where a hub **502** and/or axil **504** may be placed. The hub **502** may include a cylinder coupled to a rod like axil, which, in turn, is coupled with the flywheel coupler **312** or directly coupled with a motor **310**, gear, bearing assembly, flywheel bearing **308**, or otherwise. The hub **502** may be bolted, glued, welded, or pressure fit to the plates. For instance, during assembly, the hub **502** and plates may be placed together expanded to differing degrees based on temperature or expansion ratios and, when allowed to equalize in temperature, shrink to create tension and gripping force. The disks **510** may be disks or rings around the hub or may be solid at a center and otherwise coupled with the axil **504**.
(63) Depending on the implementation, the disks of the flywheel **304** may be coupled together by various means, such as glue, hot or cold welding, or fasteners. In some implementations, the disks may be coupled together with fasteners, such as the example bolts illustrated herein. FIG. **6**A illustrates an example bolt configuration **602** by which the flywheel disks may be attached together and, potentially, with an axil or other means of coupling the disks to a generator and/or bearing.
(64) FIG. **6**A illustrates an example configuration **602** of bolts **604** coupling the flywheel plates, axil, and/or flywheel coupling mechanism **312**. The flywheel **304** may include a plurality of bolts around a center, periphery, or otherwise, that rotate around the central axis with the metal plates. The bolts may prevent the metal plates from sliding relative to one another thereby throwing the flywheel **304** out of balance. In some instances, the bolts may provide compressive force on the plurality of disks or plates, which increases friction between the disks and increases stability of the flywheel **304**.
(65) In some implementations, the bolts may be adjusted, added, or removed to balance the flywheel **304** vertically and/or horizontally thereby reducing vibrations and risk of structural failure at high RPMs. In some instances, during assembly, a flywheel **304** may be spun at various speeds to detect harmonic frequencies and the bolts, weights, outer diameter of the disks(s) or other features may be adjusted to improve balance. Although other implementations are possible, the bolts may be placed in alternating orientations to improve balance, as illustrated. The bolts may also be tightened in a star or other pattern to balance the forces on the disks.
(66) In some implementations, a plurality of bolts may be positioned around a periphery, such as through perforations in the plates or external to the plates to provide the axial compressive force and/or radial force on the plates. For instance, the bolts may couple a top plate with a bottom plate to pull them or link them together, which may also beneficially allow rotational force to be better communicated with a motor **310** while reducing rotational or radial slippage between plates.
(67) Returning to FIGS. **5**A and **5**B, the flywheel **304** may be connected to a flywheel coupling **312**, which may form or be connected to the axil at the rotational axis to impart rotational force between a motor **310** and a flywheel **304**. The flywheel **304** coupling may include a gear, clutch, transmission, magnetic coupling, or other device. For example, as illustrated in the example of FIGS. **5**A and **5**B, the flywheel coupling **312** may include a magnetic coupling. The flywheel coupling **312** may continuously couple the flywheel **304** with the motor **310** or transmission and/or may be decouplable either electronically or manually.
(68) In the illustrated implementation, the flywheel coupling **312** may include a flywheel component **506** attached to the flywheel **304** and a motor component **508** may be attached to a motor **310** (e.g., directly or via a transmission, gears, belts, etc.). In the depicted example, a motor **310**, motor component **508**, flywheel component **506**, and axil may be axially located along a rotation of axis, which improves reliability and reduces off-axis forces.
(69) For example, as illustrated in the example, a magnetic flywheel coupling **312** may include a bottom member (e.g., a flywheel component **506**) coupled with the flywheel **304** and a top member (e.g., a motor component **508**), which may be coupled with a generator and/or motor **310**. A magnetic flywheel coupling **312** may include radially located, alternating polarity magnets, which resist movement against each other, thereby allowing a torque to be transferred between the generator-motor **310** and the flywheel(s) **304**. As illustrated, the top member may sit inside the bottom member of the magnetic flywheel coupling **312** without touching. Accordingly, a force may be applied without mechanical loses and wear and tear, thereby increasing the efficiency of the mechanical-energy storage unit and increasing its useful lifespan. Depending on the implementation, the magnetic flywheel coupling **312** may include one or more bearings (e.g., ball, magnetic, etc.) keeping the top and bottom members aligned.
(70) The components of the flywheel coupling **312** may be couplable or decouplable using various clutch mechanisms, actuators, motors **310**, or other devices that press the components towards one another or move them away from one another. In other implementations, the components (e.g., a motor component **508**) may include non-permanent magnets or deactivatable (e.g., by alternating magnetic flux with other magnets using a magnetic switch) to allow the components to be decoupled without moving them relative to one another.
(71) In some implementations, a membrane, wall, gasket, or other component may be disposed between the top and bottom portions of the flywheel coupling **312**. On the flywheel-side of the partition, a vacuum may be maintained while on the motor **310**-side of the partition a vacuum may not be used. In other implementations both halves of the flywheel coupling **312** (and/or the motor **310**) may be in or out of a vacuum. For example, a cavity housing the flywheels **304** may be sealed in a vacuum from the factory or a vacuum may be created or maintained using a pump, although other implementations are possible.
(72) It should be noted that although the example flywheel coupling **312** illustrates the magnets as being oriented radially from the rotational axis and the motor component **508** fitting partially inside of the flywheel component **506**, other implementations of a magnetic are possible. For instance, the motor component **508** may fit around the flywheel component **506** or each may include a plate facing one another. For instance, the magnets on each component may be axially oriented to interact with one another.
(73) FIG. **6**D illustrates an example flywheel coupling **312** including a motor component **508** and a flywheel component **506** illustrated as a cross section. In the depicted example, the flywheel coupling **312** may include a plurality of magnets **682***a* . . . **682***n* and **684***a* . . . **684***n* arranged circumferentially around the central axis, which allow the flywheel **304** to be mechanically decoupled from the motor **310** while the flywheel coupling **312** is imparting the rotational force. This mechanical decoupling decreases wear, for example, that would be present on a friction clutch.
(74) For example, the flywheel coupling **312** may include a first plurality of magnets **682***a* . . . **682***n* that are oriented so that their polarity or

magnetic moment extends radially. The first plurality of magnets **682***a* . . . **682***n* may be held by a flywheel coupling **312** body that holds the magnets in place through friction, mechanical forces, or adhesion, for example. As illustrated the flywheel coupling **312** body may include a top half (not shown in FIG. **6**D) and a bottom half that clamp over the magnets **682** using fasteners.

(75) The motor component **508** may include a second plurality of magnets **684***a* . . . **684***b* that are oriented so that their polarity or magnetic moment extends radially. The first set of magnets **682** may form an outer ring and the second set of magnets **684** may form an inner ring with a smaller diameter where the rings are separated by a space. The quantities of the first and second sets **682** and **684** may be equal and even. The polarity of the magnets may alternate, so that magnetic flux meshes them together and a sheering force may draw them together while allowing them to remain physically disconnected. It should be noted that, in some instances, the magnet moments of each of the sets **682** and **684** may be oriented axially (e.g., vertically when the flywheel is oriented as illustrated).

(76) Returning to FIGS. **3**A-**3**B, the MESU assembly **302** may include a motor **310** that may be coupled with the flywheel(s) **304**, for example, at a central axis, hub, or axil, by a flywheel coupling **312**. The motor **310** may be housed in a motor **310** housing, a rotor of the motor **310** may be located at the central axis and coupled with the flywheel coupling **312** to rotate with the flywheel **304**, although other implementations, such as where belts, gears, pulleys, or other devices for coupling the motor **310** to the flywheel **304** may be used. The motor **310** may serve as a motor **310** to drive the flywheel **304** and/or a generator to receive energy therefrom.

(77) In some implementations, the mechanical-energy storage unit may include or be coupled with a generator-motor **310**, which may spin up the flywheel **304** to add energy and receive energy from the flywheel **304** to send energy to an output. The generator-motor **310** may have various configurations and sizes depending on the quantity or total mass of the flywheels **304**, a target rotational velocity of the flywheels **304** or generator-motor **310**, a target efficiency, a weight rating, or other implementations. The generator-motor **310** may be coupled with various other electronics, such as an electronic control unit that measures the electrical input or output, rotational velocity of the motor **310**, health of the system, position of the flywheel coupling **312**, position of the generator lifter **316**, or other statuses. The electronic control unit may cause electrical current from an external source to be inputted into the flywheel **304** via the generator-motor **310** or outputted via the generator-motor **310**. The generator-motor **310** may also include or be coupled to various other electronics, such as inverters, a/c converters, transformers, or other electrical devices.

(78) Alternating current motors or direct current motors may be used, for example, the motor **310** may include a permanent magnet motor **310** or, in order to allow the motor **310** to freely spin, the motor **310** may be an induction motor **310** that allows the motor **310** to freely spin when current is not being applied or received, so that the flywheel **304** can freely spin (e.g., where the flywheel coupling **312** is not decouplable). Other types and configurations of motors are possible and contemplated

(79) As illustrated in the examples of FIGS. **3**A and **3**B, a motor **310** may be mounted to a flywheel housing **306** using a motor **310** frame **314**, which may hold the motor **310** to align the axis of rotation of its rotor with the axil of the flywheel **304**. In some implementations, the motor **310** frame **314** may be mounted directly to the flywheel housing **306** or it may be mounted via a coupling lifter **316** that may move the flywheel coupling **312** (e.g., a motor component **508**) and/or motor **310** to decouple it/them from flywheel **304**. For instance, a motor **310** assembly may include a frame **314**, motor **310**, coupling lifter **316**, and/or other components that support the motor **310** and/or flywheel coupling **312**.

(80) In some implementations, one or more of the generator-motor **310**, motor frame **314**, or flywheel coupling **312** (e.g., a top member thereof), may be coupled to the flywheel housing **306** via a coupling lifter **316**. For example, a coupling lifter **316** may include a mechanism for decoupling the flywheel coupling **312**, thereby allowing the flywheel **304** to spin (e.g., free wheel) with little to no resistance, thereby reducing friction losses and increasing the amount of time energy may be stored for long time periods. The linear actuators may decouple the flywheel coupling **312** by lifting a motor component **508** of the flywheel coupling **312** away from a flywheel component **506** of the flywheel coupling **312**.

(81) In some implementations, the coupling lifter **316** may lift both the generator-motor **310** and top portion of the flywheel coupling **312** via the frame, as illustrated in the example of FIG. **3**A. Although other implementations are possible, the coupling lifter **316** may include linear actuator, stepper motors attached to threaded rods or leadscrews that lift or lower the generator frame. For example, four coupling lifters **316** are illustrated in the example of FIG. **3**A. It should be noted that although the coupling lifter **316** is described as a “lifter” or “lifting” it may decouple the flywheel coupling **312** in various ways, whether moving sideways, downward, upward, or decoupling it by other means, as described elsewhere herein.

(82) In some implementations, as the coupling lifter **316** couples the flywheel coupling **312**, the flywheel coupling **312** and/or generator-motor **310** may spin up to the speed of the flywheel **304**, thereby reducing jerking or vibration of the system as the flywheel coupling **312** is coupling. In some implementations, the flywheel coupling **312** spinning up may be passive, for example, due to a fluid, friction clutch, or magnetic coupling interacting. For instance, as the magnets of the top member and bottom member of the flywheel coupling **312** are brought into proximity, the magnetic force may naturally gradually bring the couplings to the same speed. In some implementations, the speed matching may be performed or assisted using electrical current applied to the generator motor **310** to spin it up to speed (e.g., based on a sensor measuring a speed of the flywheel **304**).

(83) Returning to FIGS. **3**A-**3**B, the flywheel **304** may be housed in a flywheel housing **306**, which may be a steel, aluminum, glass, plastic, composite or other housing for providing support to the flywheel(s) **304**. For instance, the flywheel housing **306** may include a metal (e.g., aluminum or steel) plate on the top of the flywheel **304**, a metal plate on the bottom of the flywheel **304**, various reinforcing members, and housing supports for coupling the top and bottom plates. In some implementations, the top metal plate, or other components of the flywheel housing **306**, which is near moving magnets (e.g., of the generator-motor **310**, flywheel coupling **312**, or flywheel bearing **308**) may be constructed from plexiglass or another non-conductive material to reduce induced eddy currents and associated inefficiencies.

(84) FIG. **6**E illustrates an example flywheel housing **306** with motor **310** frame **314**, coupling lifter **316**, and flywheel bearing **308**. The flywheel housing **306** may include top structure **682**, a bottom structure **684**, and one or more support members **686** coupling the top structure **682** and the bottom structure **684** together and providing a cavity between the top structure **682** and the bottom structure **684** where the flywheel **304** may be located when housed in the housing. In some implementations, the flywheel housing **306** may include legs, mounting brackets, and/or bushings for coupling the flywheel housing **306** to an external structure, such as a case, cement foundation, or otherwise.

(85) In some implementations, the top structure **682** may include a steel, aluminum, composite, or other plate or other structure to which other components, such as the frame **314**, coupling lifter(s) **316**, flywheel bearing **308**, or other components may be mounted. In some implementations, the top structure **682** may also include various ribs or other structures that further reinforce the top structure **682**. In some implementations, the top structure **682** (and/or bottom structure **684**) may be non-conductive or may have breaks in the conductive material to reduce eddy currents generated by a magnetic flywheel coupling **312** or flywheel bearing **308**.

(86) The bottom structure **684** may include a bottom plate similar to the top plate but with mounting points for legs or other structures that mount the flywheel housing **306** to an external structure, although other components of the housing may also be externally attached. For instance, as noted elsewhere herein, the bottom structure **684** may include legs, brackets, and/or bushings for coupling it to an external structure and/or reducing transmitted vibrations. The bottom structure **684** and/or the legs may include levels or leveling mechanisms that allow the flywheel housing **306** to be leveled.

(87) The one or more support members **686** may include vertical braces attaching the top structure **682** to the bottom structure **684**. The support members **686** may be positioned around a perimeter of the flywheel **304** and include bolts, welds, or other fastening mechanisms that couple the components together. The support members **686** may be reinforced to mitigate external damage due to a structural failure of the flywheel **304**. Although the support members **686** are illustrated as discrete posts, they may be, include, or be coupled to a continuous structure enclosing a

cavity, which may be an actively maintained or permanent vacuum in which the flywheel **304** spins.

(88) It should be noted that other implementations are possible and contemplated herein, such as where the flywheel housing **306** is integrated into a case or enclosure. The length or size of the housing supports **686** may be set to provide strength to the mechanical-energy storage unit while accommodating various quantities of flywheels **304**/flywheel disks.

(89) In some implementations, the flywheel housing **306** may be enclosed by one or more walls. For example, in some implementations, the flywheel housing **306** may be sealed, so that the flywheel **304** is held within a vacuum, thereby increasing the efficiency of the flywheel **304**. In some instances, the entire mechanical-energy storage unit may be held within a vacuum, for example, in an external case.

(90) Depending on the implementation, the flywheel housing **306** and/or case may be reinforced to prevent exterior damage in the case where one or more of the flywheel disks fails, for example, due to being spun too quickly. In some instances, to prevent excess speed in the flywheel **304**, a mechanical and/or electrical system may decouple the flywheel **304** from power being inserted into the flywheel **304**, e.g., by decoupling the flywheel coupling **312** or electronically removing a connection to an external power supply, as described below.

(91) In some implementations, the mechanical-energy storage unit may include support legs (e.g., **318** illustrated in FIG. **3**A) coupled to the flywheel housing **306**. The support legs may couple the flywheel housing **306** to the ground and/or to a case, although other implementations are possible. In some instances, the support legs may include rubber or other decoupling mechanisms to prevent vibration transfer to/from the mechanical-energy storage unit and/or flywheel(s) **304**.

(92) In some implementations, the flywheel housing **306** may be mounted within or integrated with a case or enclosure (not shown), which may be a cylinder, box, hexagonal prism, or of another shape or configuration. The flywheel **304** or MESU assembly **302** may be placed inside the case, which may be bolted to cement, buried under ground, or otherwise placed in a safe or quiet location. In some implementations, the case may be sealed so that a full or partial vacuum may be maintained therein, although other implementations are possible.

(93) The case may hold various shapes or sizes to house various configurations of mechanical-energy storage assemblies. For example, a case or enclosure may be octagonal, round, square, or another shape. The case may be constructed from stainless steel, aluminum, plexiglass, concrete, or other material that is strong (e.g., to retain a mechanical flywheel **304** failure) or may be buried underground. In some implementations, a top of the case may be a clear panel via which visual checks can be performed thereby reducing maintenance. The case may also include various apertures via which cables, pipes, or other devices may pass.

(94) Returning to FIGS. **3**A-**3**B, the MESU assembly **302** may include a flywheel bearing **308** integrated with or coupled with the flywheel housing **306** and providing vertical and/or horizontal support to the flywheel **304**. Depending on the implementation, the flywheel bearing **308** may include fluid, magnetic levitation, ball bearings (e.g., ceramic or ceramic hybrid), Teflon®, and/or other bearings. For instance, the flywheel bearing **308** may use a first type of bearing (e.g., ball bearings) horizontally and a second type of bearing (e.g., magnetic levitation) vertically. In other implementations, the flywheel bearing **308** may be completely based on magnetic levitation. The quantity, type, and spacing of magnets in either side of a magnetic levitation bearing may be based on a total mass of the flywheel(s) **304** and/or other spinning structure.

(95) In some implementations, the flywheel bearing **308**, such as a magnetic levitation bearing, may be imposed on a center axis (e.g., an axil or hub) of the flywheel **304**. The flywheel bearing **308** may be only on the top, only on the bottom, or on both the top and bottom of the flywheel(s) **304**. For example, as illustrated the flywheel bearing **308** may include a magnetic levitation bearing housed in a housing that may be coupled with the flywheel housing **306**. The bearing housing may have magnets preloaded from the factory so that the bearing housing can be installed or replaced (e.g., with other strength bearings based on a total weight of a quantity of flywheel plates) without installers or maintenance workers encountering the danger of strong magnets, such as neodymium magnets.

(96) FIGS. **6**B and **6**C illustrate examples of a flywheel bearing **308**, according to some implementations. For example, FIG. **6**B illustrates a detail view of an example flywheel bearing body that is coupled with a flywheel housing **306** and FIG. **6**C illustrates a cross section view of an example flywheel bearing **308**.

(97) As illustrated in FIG. **6**B, the flywheel bearing **308** may include a bearing body **642** in which one or more of bearings. As illustrated, the flywheel bearing body **642** may be attached to a flywheel housing **306** at a center thereof. In some instances, during manufacturing, the bearing body **642** may be pre-assembled either separately or as part of the flywheel housing **306**. For instance, during shipping, the flywheel bearing **308** may be in a shipping position or may otherwise be adjustable for during use of the flywheel **304**. Depending on the implementation, the bearing body **642** may include one or more bolts, screws, or other devices for locking, unlocking, or adjusting the bearings. As illustrated, the bearing body **642** may include one or more apertures **644***a* . . . **644***n* through which bolts or other devices may lock or adjust the flywheel bearing **308**. For example, a bolt may adjust a magnetic levitating bearing (e.g., magnets thereof) into a more or less ideal position.

(98) In some implementations, the flywheel bearing **308** may include one or more magnets that magnetically levitate the flywheel **304** vertically and/or one or more ball bearings that position the flywheel horizontally, although other types and configurations are possible and contemplated.

(99) In the cross section of FIG. **6**C, the example flywheel bearing **308** includes a plurality of magnets **662***a* . . . **662***n* arranged around the flywheel bearing **308** in a circle. These magnets may have a common magnetic moment or polarity to interact with corresponding magnets (e.g., on an opposing part of the flywheel bearing **308**, such as on a flywheel side or housing side) having an opposite polarity to levitate the flywheel **304**. The magnets **662** may be attached to one or more disks **664** and **666** that may be leveled or otherwise moved by bolts through the bearing body **642**, as noted above. Accordingly, the flywheel bearing **308** may be preloaded before a flywheel **304** is attached and/or may be adjusted during installation or maintenance, for instance.

(100) While the flywheel bearing **308** is primarily described in reference to an upper flywheel bearing **308**, the MESU assembly **302** may include a plurality of flywheel bearings **308** or flywheel bearing **308** components. For instance, a flywheel bearing **308** and/or flywheel bearing component may be located at a top of the flywheel **304**, a bottom of the flywheel **304**, or both. In some implementations, a vertical (e.g., maglev) component of the flywheel bearing **308** may be located at a top while a horizontal (e.g., ceramic ball bearing) may be located at a top and/or bottom of the flywheel **304** and flywheel housing **306**.

(101) Although not visible in FIG. **6**C, the flywheel bearing **308** may include one or more horizontal bearings, which may include ball bearings or otherwise, such as ceramic ball bearings positioning the flywheel **304** horizontally. For example, a maglev bearing may support the weight of the flywheel **304** while a horizontal ceramic bearing supports less weight and therefore experiences less wear by keeping the flywheel **304** position at an axis of rotation. Additionally, or alternatively, various lubricants may be used or the bearings may be dry. Where lubricants are used and the MESU assembly **302**, flywheel bearing **308**, flywheel housing **306**, and/or flywheel **304** are located in a vacuum, a vacuum compatible lubricant may be used to provide lubrication and/or avoid spontaneous welding of metal surfaces.

(102) FIG. **4**A illustrates a cross section of a perspective view of an example MESU assembly **302**, and FIG. **4**B illustrates a cross section of a side view of an example MESU assembly **302**. Various components in described in reference to the other figures herein can also be seen in reference to FIGS. **4**A and **4**B. It should be noted that although an example configuration of the generator-motor **310**, flywheel coupling **312**, and flywheel **304** are illustrated, other implementations are possible and contemplated herein. For instance, a generator-motor **310** and/or flywheel coupling **312** may be disposed below the flywheel(s) **304** and lifted into place by the coupling lifter **316**. It should be noted that the interior structure of the motor **310** is no illustrated in FIGS. **4**A and **4**B.

(103) Although not illustrated in the examples of FIGS. **3**A-**4**B, other components and features may be included. For example, sensors for detecting a velocity of the flywheel(s) **304** or motor **310**, temperature of the system, maintaining or measuring a vacuum, communicating with external systems, and/or providing control of the system may also be included.

(104) FIG. **7** is a block diagram illustrating an example method **700** for operating a MESU assembly **302** to store and retrieve energy. It should be noted that it may be used with the features and technologies described herein or otherwise. The method **700** is described as being performed by a flywheel controller **254**, but it may be performed by one or more other components, control units, processors, or automated systems. As noted above, the flywheel controller **254** may include one or more processors, computer memories, communication units, and interfaces that allow it to perform operations responsive to an internal program or signals received from other devices, such as a utility server **120**, EaaS manager **110**, a mobile application, a local controller, or based on input from various sensors, such as current sensors indicating current being received or requested, rotational frequency sensors monitoring a flywheel **304** or motor **310**, or other devices. The flywheel controller **254** or other control unit may be powered by the flywheel **304**, by a battery, or by another external power source.
(105) At **702**, the flywheel controller **254** may receive an electronic message instructing the MESU to store power. The message may be received or generated by the flywheel controller **254**, for example, based on an excess voltage or current received or based on a message from a controlling application, such as the EaaS manager **110** or node application **240**, as described above. For instance, a user may select store energy on a node application **240** or the node application **240** may detect that there is excess solar production at a solar electric system **144**, in response to which, it may determine to store power at the MESU.
(106) At **704**, the flywheel controller **254** may drive a flywheel **304** of the MESU including spinning up the flywheel **304** using a motor **310** and an input current driving the motor **310**, for example, based on the received electronic message. For instance, the flywheel controller **254** may actuate an electronic or physical switch that directs a current to the motor **310** to spin the flywheel **304** up. The flywheel controller **254** may drive it up to a set speed and/or input a defined power into the flywheel **304**.
(107) At **706**, the flywheel controller **254** may receive an electronic message instructing the mechanical-energy storage unit to allow the flywheel **304** to spin. For instance, in response to a determination that the flywheel **304** has reached its target speed or storage capacity, or in response to another determination, the flywheel controller **254** may determine to allow the flywheel **304** to spin freely.
(108) At **708**, the flywheel controller **254** may decouple the motor **310** from the flywheel **304** using the flywheel coupling **312** based on the third electronic message. For instance, the flywheel controller **254** may instruct an induction motor to spin freely or a flywheel **304** coupling to decouple. For instance, the flywheel coupling **312** may include a clutch and/or a magnetic coupling, as described above. Decoupling the motor **310** from the flywheel **304** may include actuating a linear actuator that moves a motor component **508** of the flywheel coupling **312** away from a flywheel component **506** of the flywheel coupling **312**, which allows the flywheel **304** to spin freely. As noted elsewhere herein, other implementations are possible and contemplated herein.
(109) At **710**, the flywheel controller **254** may allow the flywheel **304** to spin, for example, for a defined time period, for example, until the energy is used or another signal is received indicating to output power.
(110) At **712**, the flywheel controller **254** may receive an electronic message instructing the MESU to output power. For instance, as with the operations at **702** or **706**, the flywheel controller **254** may determine or be instructed to output electrical power via from the MESU. The determination to output power may be based on a detected voltage or electrical demand, a set schedule (e.g., programmed based on a time of day), or based on another condition or signal.
(111) At **714**, the flywheel controller **254** may couple the motor **310** to the flywheel **304**, for example, via the flywheel coupling **312**. For instance, the flywheel controller **254** may actuate the flywheel coupling **312** to couple the motor-generator **310** to the flywheel **304** and generate electrical current based thereon. In some implementations, in coupling the flywheel coupling **312**, the speed of the flywheel component **506** may be matched to a motor component **508** of the flywheel coupling **312** while coupling the components.
(112) The speed matching may be active where a speed of the flywheel **304** is computed (e.g., based on a previously known RPM, elapsed time, and predicted rate of deceleration) or sensed using a sensor and the flywheel controller **254** may instruct the motor **310** to spin to the corresponding speed while coupling in order to reduce jerking or friction.
(113) In some implementations, the speed may be matched passively. For example, as magnets on each component of the flywheel coupling **312** get closer, they may passively match speeds.
(114) At **716**, the flywheel controller **254** may output an electrical current including driving the motor(s) **310** using the flywheel **304** via the flywheel coupling **312**, for example, based on the received electronic message. For example, the flywheel controller **254** may use the motor-generator **310** to slow the flywheel **304** and thereby generate a current, which may be used or transmitted to an external load.
(115) It should be noted that other implementations and operations are possible and contemplated, for example, where a mechanical-energy storage system may include a flywheel **304** constructed from a steel or aluminum core with composite wheel on the radially outward portions, thereby allowing the flywheel **304** to spin at faster speeds without failure. Additional mechanical-energy storage units may be stacked and coupled (e.g., within a single case), thereby increasing storage capacity.
(116) In the foregoing description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the technology. It will be apparent, however, that the technology described herein can be practiced without these specific details.
(117) Reference in the specification to “one implementation”, “an implementation”, “some implementations”, or “other implementations” means that a particular feature, structure, or characteristic described in connection with the implementation is included in at least one implementation of the disclosure. The appearances of the term “implementation” or “implementations” in various places in the specification are not necessarily all referring to the same implementation.
(118) In addition, it should be understood and appreciated that variations, combinations, and equivalents of the specific implementations, implementations, and examples may exist, are contemplated, and are encompassed hereby. The invention should therefore not be limited by the above-described implementations, implementations, and examples, but by all implementations, implementations, and examples, and other equivalents within the scope and spirit of the invention as claimed.

Claims

1. A mechanical-energy storage unit assembly comprising: a flywheel including one or more plates and coupled at a central axis of rotation to a flywheel bearing assembly, the flywheel being adapted to rotate about the central axis; a flywheel housing providing vertical support to the flywheel bearing assembly; the flywheel bearing assembly coupling the flywheel to the flywheel housing, the flywheel bearing assembly including one or more magnets located at a top of the flywheel, the one or more magnets lifting the flywheel toward the top of the flywheel housing; a motor assembly including a motor adapted to convert an input electrical current to rotational momentum by spinning up the flywheel, the motor further being adapted to convert the rotational momentum of the flywheel into an output electrical current; and a flywheel coupling adapted to couple the motor assembly with the flywheel and impart rotational force between the motor and the flywheel.
2. The mechanical-energy storage unit assembly of claim 1, wherein: the one or more plates include a plurality of metal plates stacked together.
3. The mechanical-energy storage unit assembly of claim 2, wherein: the flywheel includes a plurality of bolts that rotate around the central axis with the plurality of metal plates; and the plurality of bolts adapted to provide compressive force on the plurality of metal plates, the compressive force increasing friction between the plurality of metal plates.
4. The mechanical-energy storage unit assembly of claim 1, wherein: the flywheel housing includes a top structure, a bottom structure, and one or

more support members coupling the top structure and the bottom structure together and providing a cavity between the top structure and the bottom structure, the flywheel being located in the cavity when housed by the flywheel housing; the flywheel bearing assembly is coupled with one or more of the top structure and the bottom structure; and the flywheel housing includes one or more bushings coupling the flywheel housing to an external structure.

5. The mechanical-energy storage unit assembly of claim 1, wherein: a rotor of the motor is located at the central axis and coupled with the flywheel coupling to rotate with the flywheel.

6. The mechanical-energy storage unit assembly of claim 1, wherein the flywheel coupling imparting the rotational force between the motor and the flywheel includes: a plurality of magnets arranged circumferentially around the central axis, the flywheel coupling being adapted to allow the flywheel to be mechanically decoupled from the motor while the flywheel coupling is imparting the rotational force.

7. The mechanical-energy storage unit assembly of claim 6, wherein: the flywheel coupling includes a flywheel component coupled with the flywheel and a motor component coupled with the motor, the flywheel component interacting with the motor component using magnetic flux to impart force on the motor component; the flywheel component includes a first plurality of magnets in the flywheel component and located radially relative to the central axis; and the motor component includes a second plurality of magnets in the motor component and located radially relative to the central axis.

8. The mechanical-energy storage unit assembly of claim 7, further comprising: the first plurality of magnets are polarized in a radial direction outward from the central axis, a magnetic moment of each of the first plurality of magnets being oriented in an alternating direction from an adjacent magnet of the first plurality of magnets; and the second plurality of magnets are polarized in the radial direction outward from the central axis, a magnetic moment of each of the second plurality of magnets being oriented in an alternating direction from an adjacent magnet of the second plurality of magnets.

9. The mechanical-energy storage unit assembly of claim 1, wherein: the flywheel coupling is connected to a control unit, the control unit electronically decoupling the flywheel coupling based on a received electronic signal.

10. The mechanical-energy storage unit assembly of claim 9, wherein: the flywheel coupling is coupled with one or more linear actuators, the one or more linear actuators adapted to decouple the flywheel coupling by lifting a motor component of the flywheel coupling away from a flywheel component of the flywheel coupling.

11. The mechanical-energy storage unit assembly of claim 10, wherein: the one or more linear actuators are further adapted to decouple the flywheel coupling by lifting the motor away from the flywheel component of the flywheel coupling.

12. The mechanical-energy storage unit assembly of claim 1, wherein the flywheel bearing assembly includes: the one or more magnets that magnetically levitate the flywheel vertically; and one or more ball bearings that position the flywheel horizontally.

13. The mechanical-energy storage unit assembly of claim 1, wherein: the flywheel housing includes a vacuum chamber, the flywheel being located within the vacuum chamber.

14. The mechanical-energy storage unit assembly of claim 1, wherein: the motor assembly includes a frame coupling the motor to the flywheel housing and adapted to support the motor along the central axis from the flywheel coupling.

15. The mechanical-energy storage unit assembly of claim 1, wherein: the flywheel bearing assembly includes a plurality of adjustment mechanisms adapted to adjust one or more magnets of a magnetic levitation bearing.

16. The mechanical-energy storage unit assembly of claim 1, further comprising a mechanical-energy storage unit control system coupled with the motor and the flywheel coupling, the mechanical-energy storage unit control system including one or more processors adapted to execute instructions that cause the mechanical-energy storage unit assembly to: receiving a first electronic message instructing the mechanical-energy storage unit assembly to store power; driving the flywheel including spinning up the flywheel using the motor and an input current based on the first electronic message, the flywheel including a plurality of metal plates coupled with the motor using the flywheel coupling; allowing the flywheel to spin for a defined time period; receiving a second electronic message instructing the mechanical-energy storage unit control system to output power; and outputting an electrical current including driving the motor using the flywheel via the flywheel coupling based on the second electronic message.

17. A computer-implemented method for controlling a mechanical-energy storage unit comprising: receiving, by one or more processors, a first electronic message instructing the mechanical-energy storage unit to store power; applying, by the one or more processors, an input current from one or more external circuits to a motor that causes the motor to impart rotational force that increases a rotational momentum of a flywheel of the mechanical-energy storage unit based on the first electronic message, the flywheel including a plurality of metal plates coupled with the motor using a flywheel coupling; allowing, by the one or more processors, the flywheel to spin for a defined time period including: receiving, by the one or more processors, a second electronic message instructing the mechanical-energy storage unit to allow the flywheel to spin; and based on the second electronic message, decoupling, by the one or more processors, the motor from the flywheel using the flywheel coupling; receiving, by the one or more processors, a third electronic message instructing the mechanical-energy storage unit to output power; and causing, by the one or more processors, the motor to decrease the rotational momentum of the flywheel by receiving rotational force from the flywheel, the motor converting the rotational momentum into an output electrical current and outputting the output electrical current to the one or more external circuits based on the second electronic message.

18. The computer-implemented method of claim 17, further comprising: receiving, by the one or more processors, a third electronic message instructing the mechanical-energy storage unit to allow the flywheel to spin; and based on the third electronic message, decoupling, by the one or more processors, the motor from the flywheel using the flywheel coupling.

19. The computer-implemented method of claim 18, wherein: decoupling the motor from the flywheel includes actuating a linear actuator to move a motor component of the flywheel coupling away from a flywheel component of the flywheel coupling.

20. A system comprising: a flywheel including one or more plates and coupled at a central axis of rotation to means for allowing the flywheel to rotate about the central axis; a flywheel housing providing support to the means for allowing the flywheel to rotate about the central axis; means for converting an input electrical current to rotational momentum by spinning up the flywheel; means for converting the rotational momentum of the flywheel to an output electrical current; and means for coupling the flywheel to one or more of the means for converting the input electrical current to the rotational momentum and the means for converting the rotational momentum of the flywheel to the output electrical current.