CONTROLLER FOR HYBRID ENERGY STORAGE

FIELD

The present application relates to energy storage for a power grid, and, particularly, to using multiple energy devices having different response times in combination for energy production.

BACKGROUND

Grid energy storage (also called large-scale energy storage) refers to the methods used to store electricity within an electrical power grid. Electrical energy is stored during times when production (from power plants) exceeds consumption. The excess energy stored can be used at times when consumption exceeds production. Using such techniques, electricity production need not be drastically scaled up and down to meet consumption.

There are a variety of forms used for energy generation and storage. Some well-known devices include hydroelectric dams (using a water reservoir), combined cycle units (e.g., combined gas and steam turbines), gas turbines, coal units, pumped storage hydro (pumping water to a high elevation storage reservoir), flywheels (storing energy using a rotational disc), compressed air, batteries (e.g., sodium-sulfur, lithium-ion, flow, etc.), super capacitor bank, etc. Intermittent energy sources, such as wind turbines, photovoltaics, and tidal, can also provide energy to the grid, but such sources are by nature unpredictable, as production can vary not only seasonally and regionally, but from minute to minute.

Some such forms of energy storage and energy generation react slowly to changes in an input regulation signal, while others react quickly. For example, hydroelectric, coal, gas and combined cycle units are traditionally very slow in reacting to a change in regulation signals (1-6 minutes to exceed 90% capacity), while batteries and flywheels can react much faster (less than 1 minute, but can be 5 seconds or less to exceed 90% capacity), and, in some cases, nearly instantaneously.

Hybrid energy storage systems combine both fast and slow units. Based on a regulation input signal, a control algorithm determines the optimal distribution of the requested regulation on the participating units. The algorithm calculates operating points for each unit, which are then supplied to the unit models. For combined hydro and flywheel models, the set point is modified dynamically to compensate for hydro plant delays.

Nonetheless, the control algorithm still suffers in that the slow unit tracks the regulation signal substantially all of the time. Such tracking places a high burden and wear on the slow units.

Thus, a more efficient controller is desirable for hybrid energy storage systems.

SUMMARY

The present application provides a controller that reduces wear and tear on hybrid systems by having only a fast unit tuned to track fluctuations of a regulation signal in a normal mode of operation. By contrast, the slow unit does not track fluctuations in the regulation signal in the normal mode of operation, which reduces wear and tear on the slow unit.

In one embodiment, a method for a regulation service is provided that uses a first energy unit and a second energy storage unit. The first energy unit can be a storage unit, such as pumped hydro storage, or an energy generation unit, such as a hydroelectric dam or a gas turbine. The second energy storage unit can be a fast unit, such as a battery or a flywheel. If the second energy storage unit is within a desired energy range, it is used to substantially track changes in the regulation signal while the first energy unit remains at a substantially constant power output.

In another embodiment, only when the second energy storage unit state of charge falls below or above threshold levels does the slow unit react and track the regulation signal, which helps to charge or discharge the second unit.

In yet another embodiment, energy band parameters associated with the threshold levels can be dynamically modified in order to improve the regulation performance, optimize the efficiency of the hybrid system, and reduce wear and tear on the hybrid system.

The combined hybrid system can provide faster and more accurate regulation service than a single unit acting on its own. Additionally, a fast unit can be tuned to significantly reduce the adjustments of a slow unit's regulation curve, thereby extending the life of the slow unit and reducing overall cost of power. Additionally, the fast unit can maintain an output of the slow unit at substantially near the most efficient operating point. By proper selection of the fast unit's energy bands, the fast unit's energy can be adjusted to efficiently use the entire available energy range.

The foregoing and other objects, features, and advantages of the invention will become more apparent from the following detailed description, which proceeds with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a system diagram showing a hybrid energy system.

FIG. **2** is a controller that can be used in the hybrid energy system of FIG. **1**.

FIG. **3** is a flowchart of a method for providing a regulation service to an electrical power grid.

FIG. **4** is a flowchart of a method for dynamically modifying energy bands in providing a regulation service.

FIG. **5** is an example showing energy bands used in the regulation service.

FIG. **6** is a detailed flowchart showing different actions performed based on the state of energy in the hybrid system.

FIG. **7** is a continuation of the flowchart of FIG. **6**.

FIG. **8** is a flowchart of a method for determining a regulation status of a slow unit.

FIG. **9** is a flowchart of a method of actions performed in a normal mode of operation.

FIG. **10** is a flowchart of a method of actions performed for charging a storage unit in the hybrid energy system.

FIG. **11** is a flowchart of a method of actions performed for discharging a storage unit in the hybrid energy system.

DETAILED DESCRIPTION

FIG. **1** shows a hybrid energy storage system **100** used to provide a regulation service in an electrical power grid **110**. A regulation signal **112** indicates a change of output needed in the hybrid energy storage system in order to meet an imbalance on an electrical power grid. Two energy devices **120**, **122** provide energy to the grid **110** and are coordinated by a controller **130** in order to track the regulation signal. The first energy device **120** can be considered a slow unit, which can be a slow energy storage unit or conventional generation unit. This group includes one or more of the following: a pumped hydroelectric storage, hydroelectric, combined cycle, gas tur-