chart can be considered an extension of FIGS. **6** and **7** when the second device is discharged. In decision block **1110**, a check is made whether the regulation service exceeds the maximum capacity of the fast unit. If so, then in process block **1112**, the power of the slow unit is set to the regulation service less the maximum power of the fast unit and the power from the fast unit is set to a maximum (process block **1114**). In decision block **1120**, a check is made whether the regulation service is greater than or equal to the maximum capacity of the fast unit plus the minimum regulation power capacity of the slow unit. If so, then in process block **1122**, power of the fast unit is set to the regulation service required, while the power output of the slow unit used for regulation service is set to 0. If decision block **1120** is decided in the negative, then in process block **1130** the power output of the fast unit is set to the regulation service required minus the regulation service required from the slow unit, which is set at the minimum regulation power capacity of the slow unit (process block **1132**).

Thus, it can be seen in the disclosed embodiments, that based on the input signal, a control algorithm determines the optimal distribution of the requested regulation on the participating units. The algorithm calculates setpoints for each unit, which are then supplied to the generation units. The outcome is time series of slow power plant output, fast unit energy state, and fast unit power output. Two control algorithms have been developed for different capacity ratio between the fast and slow unit. If the fast regulation capacity is dominant, the slow unit only need provide energy support to the fast unit because the fast unit can take care of all the fluctuations of the regulation signal most of the time. But with the decrease of the capacity ratio between fast and slow units, the fast unit can have more fade time if it is controlled to meet all the fluctuations of the regulation signal. Therefore, a different control algorithm can split the signal into low frequency components and high frequency components. The fast unit picks up the high frequency components and the slow unit picks up the low frequency components. Thus both good regulation performance and less wear and tear are achieved.

Two energy bands are used to define the charging status of the fast unit. If the charging status of the fast unit is within the inner band, the fast unit is controlled to take the whole regulation signal except the capacity needed by the regulation signal is out of the capacity range of the fast unit. The charging status of fast unit between the inner energy band and outer energy band works like hysteresis. If the change direction of the fast unit charging status is going out of the inner energy band, no special action is needed until the charging status is out of the outer energy band. The slow unit will jump in to charge up or discharge the fast unit back to the inner energy band. If the slow regulation capacity is dominant, a low pass filter can be used to separate the regulation signal. The cut-off frequency of the low-pass filter is decided by both considering the capacity constraints and ramp capability of fast and slow units.

Although the operations of some of the disclosed methods are described in a particular, sequential order for convenient presentation, it should be understood that this manner of description encompasses rearrangement, unless a particular ordering is required by specific language set forth below. For example, operations described sequentially may in some cases be rearranged or performed concurrently. Moreover, for the sake of simplicity, the attached figures may not show the various ways in which the disclosed methods can be used in conjunction with other methods.

Any of the disclosed methods can be implemented as computer-executable instructions stored on one or more computer-readable storage media (e.g., non-transitory computer-readable media, such as one or more optical media discs, volatile memory components (such as DRAM or SRAM), or nonvolatile memory components (such as hard drives)) and executed on a computer. Any of the computer-executable instructions for implementing the disclosed techniques as well as any data created and used during implementation of the disclosed embodiments can be stored on one or more computer-readable media (e.g., non-transitory computer-readable media). The computer-executable instructions can be part of, for example, a dedicated software application or a software application that is accessed or downloaded via a web browser or other software application (such as a remote computing application). Such software can be executed, for example, on a single local computer (e.g., any suitable commercially available computer) or in a network environment (e.g., via the Internet, a wide-area network, a local-area network, a client-server network (such as a cloud computing network), or other such network) using one or more network computers.

For clarity, only certain selected aspects of the software-based implementations are described. Other details that are well known in the art are omitted. For example, it should be understood that the disclosed technology is not limited to any specific computer language or program. For instance, the disclosed technology can be implemented by software written in C++, Java, Perl, JavaScript, Adobe Flash, or any other suitable programming language. Likewise, the disclosed technology is not limited to any particular computer or type of hardware. Certain details of suitable computers and hardware are well known and need not be set forth in detail in this disclosure.

Furthermore, any of the software-based embodiments (comprising, for example, computer-executable instructions for causing a computer to perform any of the disclosed methods) can be uploaded, downloaded, or remotely accessed through a suitable communication means. Such suitable communication means include, for example, the Internet, the World Wide Web, an intranet, software applications, cable (including fiber optic cable), magnetic communications, electromagnetic communications (including RF, microwave, and infrared communications), electronic communications, or other such communication means.

The disclosed methods, apparatus, and systems should not be construed as limiting in any way. Instead, the present disclosure is directed toward all novel and nonobvious features and aspects of the various disclosed embodiments, alone and in various combinations and subcombinations with one another. The disclosed methods, apparatus, and systems are not limited to any specific aspect or feature or combination thereof, nor do the disclosed embodiments require that any one or more specific advantages be present or problems be solved.

In view of the many possible embodiments to which the principles of the disclosed invention may be applied, it should be recognized that the illustrated embodiments are only preferred examples of the invention and should not be taken as limiting the scope of the invention. Rather, the scope of the invention is defined by the following claims. We therefore claim as our invention all that comes within the scope of these claims.

We claim:

1. A method of providing regulation service using a hybrid energy storage system, comprising: providing a regulation service to an electrical power grid using a first energy unit and a second energy storage unit; receiving a regulation signal indicative of a change of output needed to meet an imbalance