FREQUENCY RESPONSIVE CHARGE SUSTAINING CONTROL OF ELECTRICITY STORAGE SYSTEMS FOR ANCILLARY SERVICES ON AN ELECTRICAL POWER GRID

BACKGROUND OF THE INVENTION

[0001] The present disclosure relates to the provision of ancillary services on a power grid, and more specifically to frequency regulation and synchronized reserve using electricity storage systems.

[0002] For any given period of time, e.g., one day, electricity grid operators estimate the amount of energy needed for each second, minute, or hour of that period of time. Electricity providers supply this estimated amount of energy via power plants. In general, the average of the actual load is relatively close to the estimated amount. However, there are instantaneous fluctuations in the amount of energy that is required, causing the actual load to be higher than the estimate or lower than the estimate.

[0003] In response to such fluctuations, the electricity providers alter the output of electrical power from the power plants in order to match the load. This change in the output of the on-line power plants is termed "load following". When the load is higher than the power being delivered, it is intuitive that the power needs to increase so that electrical devices remain fully operational. FIG. **1** is a plot illustrating an actual load **110** and a load following **120** by the power plants. As can be seen, on-line power plants are not able to exactly match the actual load fluctuations. There is also a second, less intuitive reason that the power needs to equal the load. If the supplied power is different from the power load, the frequency of the AC current supplied to homes and businesses will differ from the nominal standard, e.g. 50 Hz or 60 Hz. This difference in frequency can cause appliances, lighting, and other devices to operate inefficiently, or even in an unsafe manner.

[0004] To maintain the required operating frequency of the AC current, power system operators call on power plants to provide an additional service called frequency regulation. In FIG. **1**, line **130** illustrates how frequency regulation requires moment by moment adjustments of more and less power to maintain the frequency in the desired operating range. If the load (demand) is lower than the power being supplied, the output frequency increases above 60 Hz. Conversely, if the load is greater than supplied power, the frequency decreases (as the generators slow their energy production). Other similar ancillary services also respond to deviations in the frequency of the power grid, such as synchronized reserve which involves fast response power plants that are already synchronized with the frequency of the grid and can begin supplying energy very quickly in the event of the failure or other problem with the power supply. Services such as frequency regulation and synchronized reserve generally fall into a category referred to as Ancillary Services to the power grid, as these services operate to support the core requirements of providing power and energy for consumption.

[0005] Historically, frequency regulation, synchronized reserve and other ancillary services have been provided by power plants. However, energy storage technologies, such as batteries, flywheels, capacitors, or other devices can also be used to supply energy to the electrical power grid. These energy storage technologies, by their nature, also have the capability to take excess energy from the grid to be stored for later use as well as discharge energy to the grid. Since frequency regulation requires constant adjustments of both adding and subtracting the total energy in the system from moment to moment (see FIG. **1**, line **130**), energy storage technologies are well suited to meeting this need.

[0006] Energy storage technologies do not directly create new energy, but allow for an increased efficiency in the use of the energy generated by power plants, by better matching it to the instantaneous change in needs on the power grid. This efficiency will allow for lower total cost and lower emissions in relation to operating the power system. In addition, energy storage technologies supplying ancillary services allows existing power plant energy capabilities to be focused on the production of energy for consumption rather than being diverted to services required to maintain the power grid, potentially delaying the need for new power plants as demand rises over time.

[0007] However, most energy storage technologies, when compared to power plants, are constrained in the amount of total energy or duration of energy that can be supplied or withdrawn from the electrical power grid. For example, in the case of battery energy storage systems, the battery may reach a point of being out of energy or completely full of energy and thus unable to perform the regulation function required in that instant. However, given the up and down moment-by-moment fluctuations needed for effective frequency regulation on the power grid, an energy storage unit that is unable to perform one moment, such as the case where the battery is empty and energy is needed, would be able to perform in the next instant, such as the case where the empty battery is now available to absorb excess energy. To meet this challenge, energy storage technologies need mechanisms, process, and controls that enable the most effective charge sustaining operating pattern of the energy storage unit in meeting the needs of frequency regulation and other ancillary services.

[0008] Although generic control systems for energy storage technologies connected to a power grid have been proposed, actual systems that can reliably sustain the capability of the system for ancillary services on the power grid have not been achieved. Therefore, it is desirable to have a control system for energy storage systems that can reliably coordinate the state of charge (SOC) or capacity to store or discharge energy of the energy storage system with the moment-by-moment needs of the power grid for frequency regulation, synchronized reserve and other ancillary services. Further, it is desirable that such control system operate to restore the energy storage system to an optimal SOC in a manner that sustains the ongoing capability of the energy storage unit to be able to respond to dispatch or automatic signals for these services.

SUMMARY

[0009] Disclosed embodiments provide systems, apparatus, and methods for controlling the charge and discharge behavior of a energy storage systems energetically coupled to the electricity grid such that it provides for sustained availability of charge and discharge capability suitable for frequency regulation and other ancillary services to the power grid when needed, and recovers to a specified level of state of charge (SOC) when not in active use and grid conditions permit. When an operator requests regulation (i.e. adding or removing energy from the grid) by dispatch or through automated control, the control mechanism confirms that the SOC value will allow the requested charge or discharge and then