Towards future distribution power system – facilitating technologies: constant frequency methods for operating autonomous microgrids and massive energy storage

Future distribution power system could be evolved into multiple microgrids interconnected through solid-state transformers. Such systems combine conventional generation with renewable energy generation, have grid-scale massive energy storage, could operate in both grid-connected and autonomous modes, feature both AC microgrids and DC microgrids, and are facilitated by advanced communication tools and multiple agents etc.

This speech covers two aspects of such future distribution power system: 1) constant frequency methods for operating autonomous microgrids; 2) massive energy storage.

Constant frequency method for operating autonomous microgrids

With the imminent depletion of fossil fuel, renewable energy generations, such as solar and wind energy harnessing etc have been widely adopted worldwide. To minimize reliance on fossil fuel, microgrids with autonomous operation capability have been investigated intensively in recent years. Microgrids can be in the form of DC microgrids, AC microgrids or a mixture of two. For existing AC distribution power systems, potentially they can be converted into multiple interconnected AC microgrids with autonomous operation capability. These could become a reality after cost-effective and environment-friendly and highly efficient grid-scale massive energy storage problems are solved. To operate such autonomous AC microgrids, one may adopt a method based on either frequency against real power droop and voltage against reactive power droop or partitioning plus constant frequency method. The former method is currently undergoing intensive upstream research, which is tremendously effort taking procedure. This is because inverters have no large inertia as conventional generators do. To harmonize inverter based generation with conventional generation still needs intensive research efforts. Nevertheless one may use partitioning plus constant frequency method to manage such converted microgrids. The whole system can be divided into multiple regions, some of which only or predominantly contain conventional generations while other of which only contain or predominantly contain renewable generations. Back-to-back converters are used to interconnect all the regions. One may use well-established methods to operate those regions with only or predominant conventional generations. For the regions with only or predominant renewable generations, one may use constant frequency methods.

Review on grid-scale heavy mass based massive energy storage

Re-vamping existing distributed power systems is an ongoing world-wide project in order to maximize the harnessing of renewable energy generation. This is a part of progress towards future smart grid. The smart grid ideally is formed by many microgrids/grids, each or some of which has the capability to operate in islanded mode.

Renewable energy mainly includes wind energy, solar energy, geo-thermal energy and tidal wave energy etc. Most of them are intermittent. To cope with such intermittence, massive energy storage is indispensable. Currently there are many existing energy storage systems, such as battery storage, hydro-power storage, fly-wheel storage, super-conducting magnetic energy storage, super-capacitor energy storage etc. Each of them has its pros and cons.

Battery storage is the most convenient one. A battery energy storage with 1kWh capability currently costs around 300USD. For massive energy storage, it may not be suitable due to this high price and also its short life span. Furthermore retrieval of battery takes effort and is costly. Pumped-hydro storage using water reservoir is a feasible one only when there is spacious space and water available.

In USA patent US 8,593,012 B2, the inventors proposed to use trains to drive the heavy mass from low platform to high platform along rail tracks to store energy. In such an energy storage system, energy losses due to friction are quite high, making overall system efficiency low.

Another two USA patents US 7,973,420 B2S and US2016/0138572 A1 present a vertical lift of heavy mass through rotating machine. Such methods can effectively reduce the friction between heavy mass and guide cylinder but rotating mechanism in the machine results in large friction losses, thereby leading to low efficiency.

To overcome the friction losses in the existing heavy mass energy storage systems, this speech introduces a linear machine based heavy mass energy storage system with less losses by shifting the heavy mass vertically from low platform to high platform without rotating parts. The heavy mass can be iron ore, concretes or other materials with relatively high mass density and affordable prices.

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