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Battery energy storage system for enabling integration of distributed solar power generation

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Abstract

The grid-tied solar power generation is a distributed resource whose output can change extremely rapidly, resulting in many issues for the distribution system operator with a large quantity of installed photovoltaic devices.

Battery energy storage systems are increasingly being used to help integrate solar power into the grid. These systems are capable of absorbing and delivering both real and reactive power with sub-second response times. With these capabilities, battery energy storage systems can mitigate such issues with solar power generation as ramp rate, frequency, and voltage issues. Beyond these applications focusing on system stability, energy storage control systems can also be integrated with energy markets to make the solar resource more economical. Providing a high-level introduction to this application area, this paper presents an overview of the challenges of integrating solar to the electricity distribution system, a technical overview of battery energy storage systems, and illustrates a variety of modes of operation for battery energy storage systems in grid-tied solar applications.

Keywords: BESS, ramp rate, grid tied solar PV

1. Introduction

The integration of significant amounts of photovoltaic (PV) solar power generation to the electric grid poses a unique set of challenges to utilities and system operators. Power from grid-connected solar PV units is generated in quantities from a few kilowatts to several MW, and is then pushed out to power grids at the distribution level, where the systems were often designed for 1-way power flow from the substation to the customer. In climates with plentiful sunshine, the widespread adoption of solar PV means distributed generation on a scale never before seen on the grid. The resulting challenges can best be thought of as opportunities for both manufacturers and utilities as they roll out various Smart Grid initiatives. Grid-connected solar PV dramatically changes the load profile of an electric utility customer. The expected widespread adoption of solar generation by customers on the distribution system poses significant challenges to system operators both in transient and steady state operation, from issues including voltage swings, sudden weather-induced changes in generation, and legacy protective devices designed with one-way power flow in mind. When there is plenty of sunshine during the day, local solar generation can reduce the net demand on a distribution feeder, possibly to the point that there is a net power outflow to the grid. In addition, solar power is converted from dc to ac by power electronic converters capable of delivering power to the grid. Due to market inefficiencies, the typical solar generator is often not financially rewarded for providing reactive power support, so small inverters are often operated such that they produce only real power while operating a lagging power factor, effectively taking in or absorbing reactive power, and increasing the required current on the feeder for a given amount of real power. A radial distribution feeder with significant solar PV generation has the potential to generate most of its own real power during daylight hours, while drawing significant reactive power. Utilities in the south western United States have started to encounter power factor violations of the operating rules laid down by the regional transmission organizations (RTO) and independent system operators (ISO) who have oversight over their systems, and may incur fines for running their systems outside of prescribed operating conditions. A weather event such as a thunderstorm has the potential to reduce solar generation from maximum output to negligible levels in a very short time. Wide-area weather related output fluctuations can be strongly correlated in a given geographical area, which means that the set of solar PV generators on feeder’s down-line of the same substation has the potential to drastically reduce its generation in the face of a mid-day weather event. The resulting output fluctuations can adversely affect the grid in the form of voltage sags if steps are not taken to quickly counteract the change in generation. In small power systems, frequency can also be adversely affected by sudden changes in PV generation. Battery energy storage systems (BESS), whether centrally located at the substation or distributed along a feeder, can provide power quickly in such scenarios to minimize customer interruptions. With the right control schemes, grid-scale BESS can mitigate the above challenges while improving system reliability and improving the economics of the renewable resource, thus providing a true smart grid solution to the integration of distributed renewable energy sources to the 21st century grid. This project describes the operation and control methodologies for a grid-scale BESS designed to mitigate the negative impacts of PV integration, while improving overall power distribution system efficiency and operation. The fundamentals of solar PV integration and BESS technology are presented below, followed by specific considerations in the control system design of solar PV coupled BESS installations.

2. Block Diagram

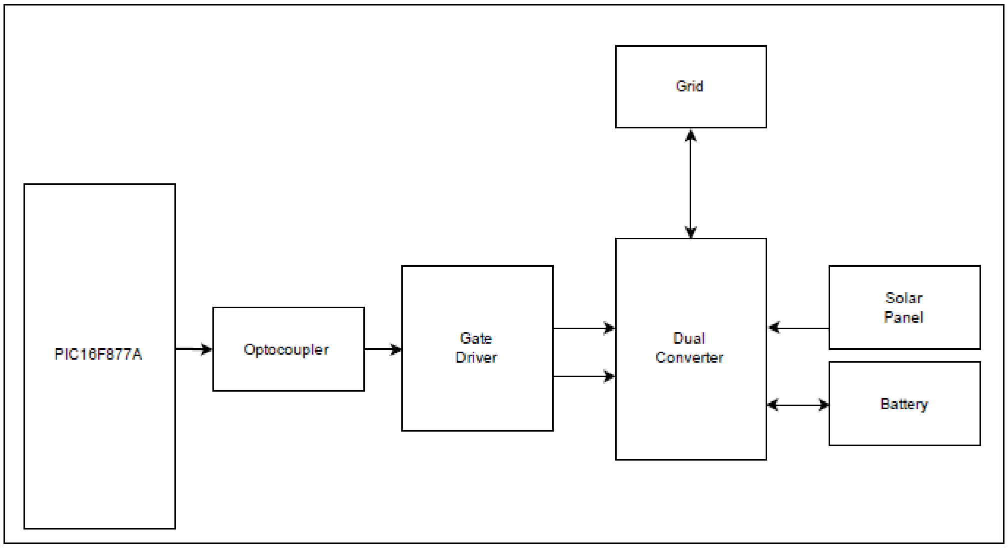

Fig 1: Proposed block diagram.

The solar panel and Battery both generate dc supply which we are going to supply to the grid. The Dc produced by solar and battery are converted into ac and supplied to grid. The opto coupler provide electrical isolation between PIC controller and dual converter. The gate driver circuit is used to provide pulses to driver circuit.

3. Battery Energy Storage System

Electrical energy in an ace system cannot be stored directly. Energy can be stored by converting the ac into dc and storing it electromagnetically, electrochemically, kinetically, or as potential energy. Energy storage technology usually includes a power conversion unit for conversion of energy. A grid-scale BESS consists of a battery bank, control system, power electronics interface for ac-dc power conversion, protective circuitry, and a transformer to convert the BESS output to the transmission or distribution system voltage level.

BESS is used for Load leveling, Mitigation of fluctuation caused by renewable energy, Enhancement of power quality, Emergency power supply Voltage control in distributed network.

3.1 Ramp Rate Control

As solar PV generation facilities have no inertial components, and the generated power can change very quickly when the sun becomes obscured by passing cloud cover. On small power systems with high penetrations of PV generation, this can cause serious problems with power delivery, as traditional thermal units struggle to maintain the balance of power in the face of rapid changes. During solar-coupled operation, the BESS must counteract quick changes in output power to ensure that the facility delivers ramp rates deemed acceptable to the system operator. Allowable ramp rates are typically specified by the utility in kilowatts per minute (kW/min), and are a common feature of new solar and wind power purchase agreements between utilities and independent power producers. Note that the ramp rate refers only to real power, and that the reactive power capabilities of the BESS can be dispatched simultaneously and independently to achieve other power system goals. The Ramp Rate Control algorithm used in the XP-DPR continuously monitors the real power output of the solar generator, and commands the unit to charge or discharge such that the total power output to the system is within the boundaries defined by the requirements of the utility.

3.2 Frequency Response

Even with ramp-rate control, there are still going to be occasional frequency deviations on the system. On small, low voltage systems, it is not uncommon to see frequency deviations of 1–3 Hz from the nominal 50 or 60 Hz frequency. Compare this to power systems in the continental United States, where many thousands of megawatts of generation are interconnected and 0.1 Hz deviation is considered significant. Such frequency deviation has adverse effects on many types of loads as well as other generators. Frequency deviation is caused by a mismatch in generation and load, as given by the swing equation for a Thevenin equivalent power source driving the grid. The system inertia is typically described using a normalized inertia constant called the H constant.

3.3 Reactive Support

In large interconnected power systems, system inertia and a diversity of generation and loads make frequency control and ramp rates a less significant concern for the distribution system operator, but rapid power flow changes can still cause adverse effects. In these cases, delivering reliable power to end-users within a specified voltage range is the most important goal. An important technical challenge for electric grid system operators is to maintain necessary voltage levels with the required stability. A distribution feeder will typically employ a combination of voltage regulators and switched or static shunt capacitors to deliver power at a consistent voltage and power factor to all customers on the line.

4. Results & Discussion

Integration of energy storage systems into the smart grid to manage the real power variability of solar by providing rate variation control can optimize the benefits of solar PV. Using the BESS to provide voltage stability through dynamic var support, and frequency regulation via droop control response reduces integration challenges associated solar PV. Coupling solar PV and storage will drastically increase reliability of the smart grid, enables more effective grid management, and creates a dispatchable power product from as-available resources.

The rapid-response characteristic of the BESS makes storage especially valuable as a regulation resource and enables it to compensate for the variability of solar PV generation. Battery energy storage systems can also improve the economics of distributed solar power generation by reduced need for cycle traditional generation assets and increasing asset utilization of existing utility generation by allowing the coupled PV solar and BESS to provide frequency and voltage regulation services

5. References

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