This study examines the use of superconducting magnetic and battery hybrid energy storage to compensate grid voltage fluctuations. The superconducting magnetic energy storage system (SMES) has been emulated by a high-current inductor to investigate a system employing both SMES and battery energy storage experimentally. The design of the laboratory prototype is described in detail, which consists of a series-connected three phase voltage source inverter used to regulate ac voltage, and two bidirectional dc/dc converters used to control energy storage system charge and discharge. “DC bus level signaling” and “voltage droop control” have been used to automatically control power from the magnetic energy storage system during short-duration, high-power voltage sags, while the battery is used to provide power during longer term, low-power undervoltages. Energy storage system hybridization is shown to be advantageous by reducing battery peak power demand compared with a battery-only system, and by improving long-term voltage support capability compared with an SMES-only system. Consequently, the SMES/battery hybrid dynamic voltage restorer can support both short-term high-power voltage sags and long-term undervoltages with significantly reduced superconducting material cost compared with an SMES-based system.