Attachment

Overview of Lithium-ion Capacitor-based System for Compensation of Short-term Power Disruptions

1 System performance

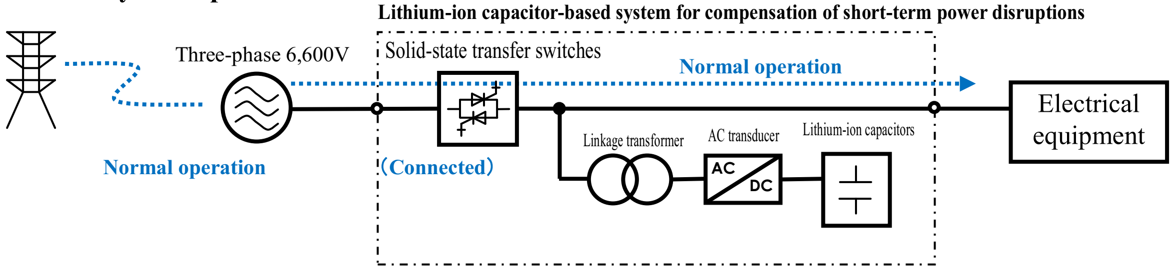
Rated voltage	Three-phase 6,600 V
Rated output capacity	1,000 kVA
Period of compensation	20 sec maximum
Energy storage method	Lithium-ion capacitors
Method of operation	Constant commercial power supply
Switching method	Uninterruptible switching (Switching time: 2 ms or less)
Efficiency in constant operation	99% or more (Excepting power for air conditioning systems)
Location for installation	Outdoors

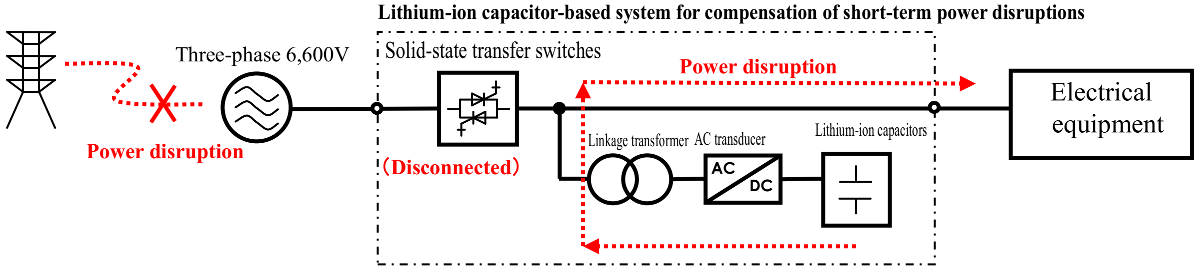
2 External view of system (System used in field trials)

System for compensation of short-term power disruptions
W 12.3 m × D 3.2 m × H 3.5 m
6,600 V, 1,000 kVA, 600 kW×11 sec compensation

Lithium-ion capacitor banks

3 Outline of system operation





4 Use of lithium-ion capacitors

Lithium-ion capacitors are hybrid capacitors, exploiting the fact that they function according to the principle of operation of electrical double-layer capacitors[*1] at their positive electrodes and the principle of operation of lithium-ion batteries[*2] at their negative electrodes to offer the characteristics of both. They are able to store approximately three times as much energy as conventional electrical double-layer capacitors.

The use of lithium-ion capacitors in the energy storage section of the newly developed system for compensation of short-term power disruptions enables the system to respond to power disruptions of up to 20 seconds in duration, meaning that its use in combination with fast-acting emergency generators is able to ensure a complete absence of power disruption.

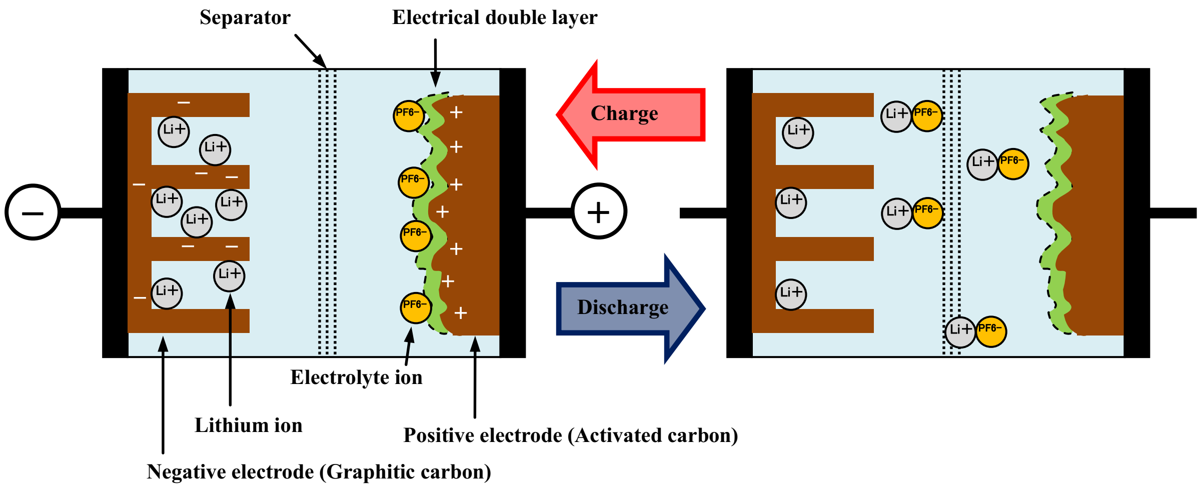
5 Other technologies applied in the system

The new system employs high-speed, high-capacity solid-state transfer switches developed for an electrical double-layer capacitor-based instantaneous voltage drop compensation system which Chubu Electric has already developed for commercial operation. The switches are highly reliable, and capable of ultra-high-speed switching. This enables the system to switch from the commercial power supply to inverter output in 2/1,000th of a second or less. In addition, the improvement of capacitor charge management has resulted in the achievement of a 99% or greater level of efficiency in constant operation (excepting power for air conditioning systems).

Because lithium-ion capacitors also require different forms of charge-discharge control to electrical double-layer capacitors (management of lower limit voltage, etc.), circuit configurations and control methods have been redesigned (for example through the use of DC circuit breakers in the charge storage section).

(Reference) Lithium-ion capacitors: Structure and principle of operation

Lithium-ion capacitors employ activated carbon in their positive electrodes. The adsorption and desorption of charge-carrying ions across an extremely thin electrical double layer that forms on the surfaces of the electrodes (the thickness of these layers is of the order of two molecules of the electrolyte solution) enables energy to be stored as capacitance (capacity to adsorb charge). The negative electrodes of a lithium-ion capacitor employ layered graphite, and store energy through adsorption of lithium ions into the layers.



Lithium-ion capacitors combine the characteristics of electrical double-layer capacitors[*1] and lithium-ion batteries[*2]. Their high voltage (3.8V) in comparison to conventional electrical double-layer capacitors enables them to realize a level of energy density (amount of electrical energy stored per unit volume) approximately three times higher, while also displaying a level of power density (electrical energy output per unit time) and a cycle life (number of possible charge-discharge cycles: around 100,000) rivaling that of electrical double-layer capacitors.

[*1] **Electrical double-layer capacitor**

Electrical double-layer capacitors use porous activated carbon in their electrodes (the same material that the positive electrodes of lithium-ion capacitors are made of), and adsorb and desorb charge-carrying ions across extremely thin electrical double layers that form at the electrodes. This enables the capacitors to realize a higher level of capacitance than standard condensers, but because their voltage is low at around 2.5V, they have a low energy density compared to other energy-storage devices.

However, because no chemical reactions occur at either the positive or negative electrodes, the capacitors also display the highest power density and cycle life (100,000 cycles or more) of the three types of energy-storage devices.

[*2] **Lithium-ion battery**

Like lithium-ion capacitors, lithium-ion batteries use graphite in their negative electrodes, but they use layered metal oxide lithium in their positive electrodes. When the batteries charge, lithium ions are drawn out of the crystal structures of the positive electrodes and inserted into the graphite layers of the negative electrodes. This gives the batteries a high voltage (4V or higher) and energy density, but because charge and discharge involves chemical reactions, their power density is low and their cycle life is short (3,000 – 5,000 cycles).