WHITE PAPER

RAIL POWER

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Ultracapacitor energy storage systems help mass transit systems avoid sudden power outages, and as an additional bonus, they yield energy savings of up to 30 percent.

If you frequently travel from place to place via tram or the underground, you are familiar with the problem of power outages. Travel suddenly comes to a stop, delays occur, and within a few minutes there may be several trains stuck one behind the other somewhere between stations – typically at peak hours, when all of the coaches are full. For individual passengers, this initially only causes a few minutes' unpleasant delay, but in a sort of chain reaction, such an incident can affect large portions of the rail network, particularly if several trains must resume their journey after being backed up in a tunnel. If they all draw energy from the same network at practically the same time, they can pull the network voltage below a critical level.

The local transport authorities of several cities such as Cologne, Germany and Madrid, Spain are now tackling this previously unsolved problem with an innovative energy storage system that is also designed to recover braking energy. This system is called SITRAS® SES, and it was developed by the engineers of Siemens Transportation Systems. It allows system operators to achieve energy savings of up to thirty percent. SITRAS® SES also makes a decisive contribution to stabilizing the network, which not only enhances the reliability of mass transit systems, but also improves the tempers of passengers.

Underground trains that feed braking energy back into the electricity supply system first entered regular service around twenty years ago. When such a train brakes, its electric motor acts as a generator and feeds the regenerated energy back into the supply lines. However, this excess energy can only be used if there is an increased energy demand somewhere else in the network, which can for instance arise from a train just starting off. Otherwise, only approximately sixty percent of the regenerated energy can be used in normal operation. The remainder is dissipated as heat in the braking resistors of the vehicles, without being put to good use. Since energy costs form a significant portion of operating budgets, amounting to 25,000 to 150,000 euros per year depending on the vehicle type, system operators have a major interest in reducing their costs by achieving energy savings.

Around four years ago, the engineers first started thinking about an energy storage system that could absorb braking energy and release it later on to trains that are starting to move. Simulations and practical tests in various cities showed that using a suitable energy storage system operationally for around 22 hours per day could reduce the annual primary energy demand by as much as 500,000 kilowatt-hours. That corresponds to a reduction of CO_2 emission of 300 tons.

Besides batteries, flywheels and capacitors, the types of devices that could be used for energy storage include exotic solutions such as superconductive motors.

A SITRAS® SES unit can absorb the braking energy released by all stopping trains within a radius of up to three kilometres (almost 2 miles)

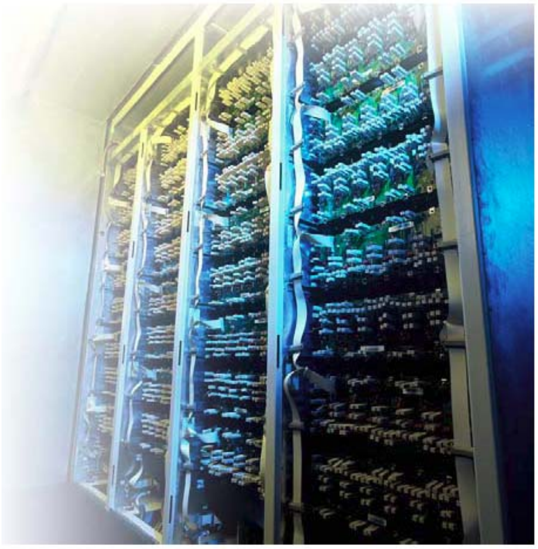
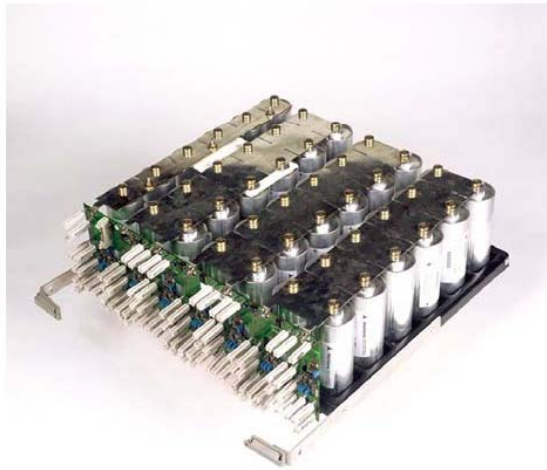
One of the two rows of cabinets including a connection unit, a voltage converter and control electronics in addition to the capacitors

However, such motors are presently still too expensive for practical use. First the engineers decided to use flywheel storage systems. But already after the first extended service tests, it was clear that they were not suitable for long-term use, due to their complex maintenance. That’s why the engineers then concentrated on developing capacitor energy storage systems.
A capacitor stores energy when mutually insulated plates are charges with opposite polarities, which causes a voltage to be created between the plates. The capacitance depends directly on the size of the plates, and it normally lies in the range of several microfarads. Special ‘double-layer’ capacitors, so called ultracapacitors from manufactures such as Maxwell, by contrast, can achieve capacitances of several thousand farads.

Ultracapacitor technology is based on an electric double layer phenomenon that has been understood for over a hundred years. However, it has only been exploited by commercial applications for about ten years. In most ultracapacitors, the electrode is carbon combined with an electrolyte. By using extremely large surface area carbon electrode, such capacitors can contain an active surface area corresponding to two football fields in a volume of half a litre. Compact in size, ultracapacitors can store an incomparably higher amount of energy than conventional capacitors. Indeed, ultracapacitors from Maxwell offered under the trademark BOOSTCAP® are currently available on the market with capacitance ranges up to 2600 Farads, and they can release that energy at very high rate. In terms of energy and power density, ultracapacitors are positioned between battery technology and electrolytic capacitor technology, combining both the high energy density of batteries, and the high power density of electrolytic capacitors. Moreover, because they are capable of cycling millions of times, they are virtually maintenance-free over the life of any product in which they are used. As a result, they need not be disposed – making them a very "green" form of energy storage.

The ultracapacitors used in the SITRAS® SES system are operated at a voltage of 2.3 volts. Each of the BOOSTCAP® capacitors has a capacitance of 2600 farads and are roughly the size of a small soda can. The complete energy storage unit contains approximately 1300 of these 2.3-volt units and the system provides a peak power capacity of one megawatt.

For practical use in an energy storage system, the 1300 ultracapacitors must be charged and discharged extremely uniformly in order to maintain their rated voltage of 2.3 V as exactly as possible. Even minute differences in charging the individual elements can reduce the performance of the overall system. Consequently, all of the capacitors are symmetrically charged during the nightly operational break, which means they are all brought to a well-defined, uniform charge level.

A glimpse into the heart of the SITRAS® SES system: The 2600 farad BOOSTCAP®s can be easily recognised

The system, which includes a connection unit, a voltage converter and control electronics in addition to the capacitors, is housed in two rows of cabinets, each of which is 3 metres long and 2.7 metres high. If one or more trains start at the same time, the SITRAS® SES system releases energy, and the network voltage never drops below the critical level. The system thus not only saves energy, with its fast response time it also prevents a sudden loss of power for the trains and thus avoids leaving hundreds of frustrated passengers sitting stranded.

Several operators of local transport networks have already recognized the benefits of the SITRAS® SES system. Siemens delivered the first energy storage system using BOOSTCAP® to the Kölner Verkehrsbetriebe AG in February 2001, and last year the first regular production model of the SITRAS® SES system also went to Cologne. In the meantime several installations are in operation; two systems have been installed in Madrid. The results speak for themselves: besides European cities, several metropolises in the USA have expressed interest in the system. A demonstration system in the USA located in Portland, Oregon, has been successfully operating since 2002.

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