WHITE PAPER

Using Ultracapacitors for Voltage Stabilization

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Using Ultracapacitors for Voltage Stabilization

Background

When an electrically-driven machine starts, it may require very high current from the power supply for a short period of time. The result of this current is often an unacceptable voltage drop due to impedance in the power supply network. This voltage drop may result in the malfunction of other equipment that is connected to the same power network. Therefore it is desirable to take measures to stabilize the voltage during the machine start or other similar events that would lead to a short-term voltage transient.

Energy storage technologies such as batteries have been proposed to resolve these voltage stabilization issues. Although batteries can store and release a large amount of energy over extended time periods, they have difficulty in providing the short-term high power levels required for voltage stabilization. In addition, batteries are slow to charge and in some applications their cycle life is notoriously short, often less than a year or two. Moreover, batteries do not perform well in cold weather. These factors limit the acceptable battery applications for voltage stabilization.

Notice that the machine start is a short process, usually lasting less than a few seconds. During this process, a large amount of power is required. Ultracapacitors, which can economically supply high currents and deliver large amounts of power in time frames as long as a few minutes, can thus act as a supplemental power supply to stabilize the network voltage during the start of a machine. Therefore the main power supply will be minimally affected. This means that other equipment connected to the main power supply will not be exposed to low voltage and be able to function normally.

Maxwell's Ultracapacitor Solutions

Maxwell's ultracapacitors have been successfully used in voltage stabilization applications in different industries, including automotive and large-scale industrial systems.

- ***Ultracapacitor-Based Voltage Stabilization in Automobiles***

Automakers around the globe are striving to improve the fuel economy of their vehicles. One increasingly popular approach is the use of stop/start systems. These systems shut off the internal combustion engine when the vehicle is stopped and restart it when the driver's foot is removed from the brake. This can reduce harmful exhaust emissions and improve fuel consumption, which also lowers CO_2 emissions. The best performing systems today use a belt-driven starter/alternator to restart the engine quickly and quietly. However, the fast start of the engine means very high current is required from the onboard battery. In practice the peak current can momentarily exceed 1000A. As a result, even though the battery and cable impedance may be very small, the voltage drop in the system can still be unacceptably high.

To avoid the voltage drop of the onboard power supply at every start, a Voltage Stabilization System (VSS) that adopts Maxwell's ultracapacitors as the energy storage device has been designed and implemented by Continental's Automotive Group. The VSS is a simple addition to the existing power network. The system is installed between the negative terminal of the battery and the chassis ground of the vehicle.

While driving or stopped, the electrical system behaves just like a conventional system. During a restart, when the system current exceeds a preset value, the VSS will switch in. At this point the charged ultracapacitors are placed in series with the battery, thus raising the available voltage. This will then raise the voltage of the entire power network. The high power density of the ultracapacitors enables them to supply the high power needed for the engine starting event, which is usually less than 1 second. In fact,

with the introduction of Maxwell's ultracapacitors, the engine starts substantially faster than before. The onboard power supply sees a higher start current but a much lower voltage drop. Moreover, the application of the ultracapacitors can enable the starting performance to stay consistent even as the vehicle battery ages, thus extending the useful life of the battery.

Since the ultracapacitors can be charged and discharged quickly (a complete charge takes less than 1 minute; a partial charge after a normal start takes only a few seconds), the VSS can effectively handle the frequent stop/start demands typical of heavy city traffic. Furthermore, Maxwell's ultracapacitors can operate over a wide operating temperature range: -40° to 65°C. This makes the VSS suitable for operation in all climatic conditions.

The VSS includes two Maxwell 1200F ultracapacitor cells in series. Besides meeting the power and energy demands of the engine starting process, the ultracapacitors are specifically designed by Maxwell to meet the stringent mechanical and environmental requirements of automotive components. These highly reliable devices are expected to operate for many years without maintenance or replacement.

- ***Ultracapacitor-Based Large-Scale Industrial Applications***

The Yangshan Deep-Water Port is a national-grade super harbor for container ships in Hangzhou Bay south of Shanghai, China. The simultaneous operations of the 26 high power, variable voltage and variable frequency ship-to-shore cranes at the port created momentary overloads which resulted in a voltage sag in the power distribution grid to which the cranes are connected.

The frequent operations and high power demands of the cranes eliminate the possibility of using batteries as a solution. Ultracapacitors on the other hand can supply the power bursts required by the cranes. Therefore ultracapacitors are able to stabilize the grid voltage during crane operations and minimize the impact of the operations of cranes on

the power grid. Further, ultracapacitors can be charged and discharged quickly and repeatedly. A charge or discharge during normal operation takes only a few seconds. The cycle life for Maxwell's products can exceed 1 million cycles. Such features ensure that the ultracapacitors provided by Maxwell can meet the frequent operation requirement of the cranes over a 10 year lifespan with minimal maintenance.

The application of the ultracapacitors at the Yangshan Deep-Water port is one of the largest ultracapacitor installations in the world and the largest in Asia. This system is composed of 126 Maxwell HTM125 modules, meaning that over 6000 3000F ultracapacitors are in place. The HTM125 has the highest power capability of any Maxwell product currently produced.

Implementing Ultracapacitors in Voltage Stabilization

Ultracapacitors can be applied in various industries and in different ways for voltage stabilization.

- If a process results in large voltage swings over a timeframe ranging from sub-second to a few minutes, ultracapacitors can be considered as a potential solution. The capability of ultracapacitors to release and absorb large amounts of power enables them to prevent voltage sags and spikes, resulting in a much smoother voltage profile.
- In many cases, Maxwell may have an ultracapacitor module suitable for the desired application, as in the Yangshan project mentioned above. If not, then a customer-designed module can be implemented with Maxwell cells to meet the specific requirements of a given application. Maxwell's Application Engineers have the expertise to assist clients in system sizing and design practices to meet a wide variety of needs.
- Ultracapacitors can be connected in series or in parallel or a mixture of both. The VSS adopts a series connection of 2 cells whereas the Yangshan project adopts a series/parallel array of modules. In general, series arrays are sized to meet the voltage requirements and parallel arrays are used to increase overall energy and power performance.

- In many systems, ultracapacitors are used to replace batteries. However, more and more engineers are discovering that ultracapacitors can be used in conjunction with batteries to both improve battery performance and extend battery life. In the above examples, the automotive system works with the vehicle battery, while the Yangshan project uses only ultracapacitors.

Benefits of Maxwell's Ultracapacitors in Voltage Stabilization

Maxwell is the global leader in ultracapacitor technology, development, manufacture and sales. Its ultracapacitors

- have very high power capability, both in charging and discharging;
- can charge and discharge rapidly and repeatedly. Depending on the specific cycle and operating environment, the cycle life can be in excess of 1 million charge-discharge cycles;
- can have a lifespan of more than 10 years, with virtually no maintenance, when used in low-stress applications;
- have a wide operating temperate range, usually from -40° to 65°C.

Maxwell's Ultracapacitor Products for Voltage Stabilization

Maxwell has a broad range of ultracapacitor module and cell products. Depending on the practical operating conditions, different modules and cells can be used for voltage stabilization.

In the above two applications, 1200F cells and HTM125 modules are used for voltage stabilization.

- BCAP1200 P270

  This cell belongs to the Maxwell K2 series of ultracapacitors. The K2 series have been proven in a wide variety of applications, with over 5 million cells in service in a variety of applications. They are designed and manufactured using Maxwell's proprietary material and assembly technologies. Typical installations using the K2

series can be found in the automotive, hybrid bus, light rail, wind turbine, and industrial machinery markets.

- HTM125 Module

  This module is rated at 125 volts. With available forced-air cooling and electronic monitoring, it is the clear choice in highly demanding applications involving heavy cycling. Typical installations using the HTM125 can be found in the hybrid bus, mining, light rail, and industrial markets.

Summary

With an increasing need for energy efficiency, today's system designers are relying on a variety of technologies to improve overall energy usage. Whether this results in an increasing reliance on renewable energy or more electrical motors in place of internal combustion engines, these systems can often place severe demands on the electrical supply network. When these demands result in unacceptable network transients, oversized power sources, low system efficiency and/or instability, ultracapacitor technology has proven to be a highly effective means of stabilizing the network. Whether that network is small or large, an ultracapacitor solution can be identified to substantially improve overall performance.