WHITE PAPER

ULTRACAPACITORS IMPROVE RELIABILITY FOR WIND TURBINE PITCH SYSTEMS

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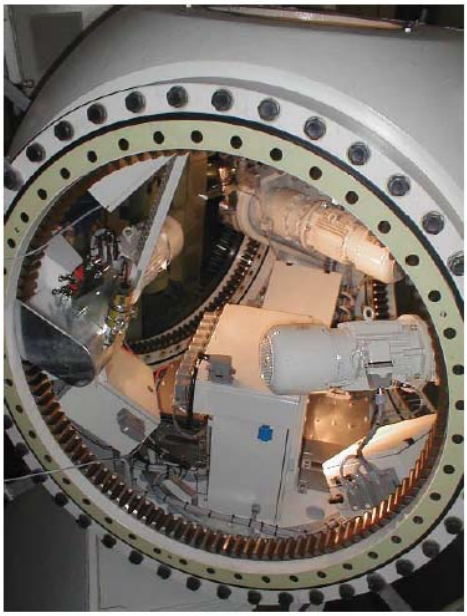
Introduction

Today's advanced wind turbines are three-bladed, variable speed turbines. The rotor blades are adjusted and controlled via three independent electro-mechanical propulsion units for the pitch systems. On a pitch controlled wind turbine the turbine's electronic controller checks the power output of the turbine several times per second. When the power output becomes too high, it sends an order to the blade pitch mechanism, which immediately turns the rotor blades slightly out of the wind. Conversely, the blades are turned back into the wind whenever the wind drops again. Thus aerodynamic efficiency and reduced loads on the drive train is assured, providing reduced maintenance and longer turbine life. To enhance the level of safety, newer wind turbine technology uses the wind not only to produce wind energy but also for its own safety. The converters feature aerodynamic braking by individual pitch control. The rotor attains the full braking effect with a 90 degree off position of all three blades. Even if a blade pitch unit fails, the other two rotor blades finish off the braking process safely. To enhance the level of safety each of the autonomous pitch systems is equipped with an emergency power supply to immediately ensure the reliable functioning of the fast blade pitch system in the event of a total power failure or for maintenance purposes.

Three bladed wind turbines



Independent electro-mechanical pitch propulsion units

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Energy Storage Technology

Currently, batteries are the most widely used component for emergency power supply. The batteries are sized to satisfy the peak power demands to adjust the rotor blades, even if those demands occur for only a few seconds. If high power is needed the deficiencies of battery storage systems are varied and they create many design challenges for pitch system engineers. Batteries have a known low temperature performance in addition to a very limited lifetime under extreme conditions. Batteries require repeated replacement throughout the life of the wind power plant and they are not designed to satisfy the most important requirements of pitch system power source which is to provide bursts of power in the seconds range for rotor blade adjustments over many hundreds of thousands of cycles.

With no moving parts, ultracapacitors provide a simple, solid state, highly reliable solution to buffer short-term mismatches between the power available and the power required. When appropriately designed with a systems approach, they offer excellent performance, wide operating temperature range, long life, flexible management, reduced system size, and are cost effective as well as highly reliable.

Maxwell Technologies offers the proprietary BOOSTCAP® ultracapacitors in several sizes, ranging from prismatic 5, 10 and 100-farad cells to cylindrical 2,600-farad large cells. We are able to supply these cells in volumes and at price points that are opening numerous market opportunities for energy storage and peak power delivery.

To facilitate adoption of ultracapacitors for applications which require integrated modules consisting of multiple ultracapacitor cells, Maxwell provides fully integrated power packs that satisfy the energy storage and power delivery requirements of fast blade pitch systems.

Integrated Ultracapacitor Power Packs

Our large cell ultracapacitors have been designed into the pitch systems of many wind turbine manufacturers and pitch system designers. Each of the autonomous pitch systems is equipped with an ultracapacitor emergency power pack to ensure the functioning of the fast blade pitch system with high reliability.

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BCAP0010, 2,600 F, 2.5 V

Ultracapacitor module for pitch control units containing 34 capacitors, a nominal capacitance of 76.5 F and a nominal voltage of 76 VDC

In the following example a layout of a pitch system is presented. Pitch systems are located in the rotating rotor hub of the wind turbine. The power supply and control signals for the pitch systems are transferred by a slip ring from the non-rotating part of the nacelle. The slip ring is connected to a unit, which includes clamps for distributing power, and control signals for the three individual blade drive units. Each of them consists of a switched mode power supply, a field bus, the motor converter, an emergency system, and the ultracapacitor bank. When the power supply is switched on, the ultracapacitor module is charged to its nominal voltage. Typical charging time is approximately 1 minute. The capacitor module has a high enough energy content to run the system for more than 30 seconds with nominal power. The ultracapacitor module is directly connected to the DC link of the motor converter. The converter then drives a 3-phase, 4-pole asynchronous motor that is mounted directly to the gearbox of the blade drive. The motor is designed to give a maximum torque at very low rpm. Each blade has sensors that control the blade position.

Ultracapacitor emergency power pack sub-module for MW class turbines. It contains 32 capacitors, a nominal capacitance of 19 or 81 F and a nominal voltage of 75 VDC

Manufacturers continue to reach for the stars as installations grow ever larger. Megawatt class turbines dominate much of the actual world market, pushing the average installed capacity per turbine above the 1 MW mark. Several wind power plant manufacturers are in development of multi-megawatt turbines, as the offshore market may demand such installations. The largest turbines are able to produce

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power up to 5 MW with rotor diameter of up to 110 m (360 ft). To ensure the functioning of the fast blade pitch system even for such large installations, bigger emergency power packs have to be integrated. Maxwell's integrated packs assembled with large ultracapacitors are perfectly suited to fulfill the requirements of megawatt class turbines. To obtain the standard nominal voltage of 300 VDC used for such wind turbines, four 75 V sub-modules are connected in series.

Offshore Installations

Due to their high reliability, efficiency and operating lifetime, ultracapacitors are especially ideal for offshore and remote wind power applications. Ultracapacitors are fundamentally viewed as maintenance-free devices that do not require costly test runs and expensive management systems versus batteries, which require ongoing evaluation of their state of health (SOH) and state of charge (SOC). Reliable and maintenance free operation is a must for offshore applications because the power plants are several kilometres away from the coast and thus a daily inspection is not possible. In winter or during stormy weather conditions, the inspection cycles can even extend to several months.

Market potential

Currently, there are more than 60,000 wind turbines operating worldwide, which represent 32 gigawatts of installed capacity. Of these, offshore installations account for 3% of the world market. It is expected that by 2007, offshore wind power generation will account for 14% of the world's new wind capacity. Though the wind energy contributes less than one-half percent of the total world electricity supply today, it is estimated, that by 2012, wind's growing contribution will reach 2%. Therefore, within a decade, another 145 GW of new capacity is expected to be installed which represents a market potentially worth $150 billion US.

The implication of these estimates is that a staggering number of new turbines will be added to networks by then, representing a high potential for advanced three-bladed variable speed turbines that feature aerodynamic braking by individual pitch control. Without question these "future" turbines require ultracapacitors as they provide a simple, solid state, cost effective, long-life solution that ensures the functioning of the fast blade pitch system with the highest reliability.

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