Development of EDLC-Based Power Supply Unit for Pitch Drive Systems for Wind Turbines

Electric double layer capacitor, Energy saving, Product lifecycle, Global environment, Wind turbine, Renewable energy resource

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Abstract

A control unit with an emergency power supply and which moves the blade pitch angle without outside power supply to the stop position was developed to stop wind-power generators safely when a system power supply was cut off by lightning.

MEICAP has the advantages of electric double layer capacitor: long-term storage and less impact on performance by frequent charge and discharge cycles. Drawing on such outstanding features, it was applied to emergency power supply units for pitch drive systems. For wind turbine systems and generators, the Company developed MEICAP 600S3 which features greatly improved safety and reliability. MEICAP is provided to domestic and foreign blade makers and is planned for global business expansion to be adopted in many systems in the future.

1. Preface

Our Electric Double Layer Capacitor (EDLC), called "MEICAP," stores electrical energy by physical adsorption effects. Rechargeable battery, the EDLC is less influenced by repeated charge and discharge cycles, and such a feature is useful for maintenance because it does not require periodic charging work during maintenance time. Making full use of this feature accordingly, the EDLC has been actively utilized as an emergency power supply unit for the motor-powered pitch control system.

This paper introduces the basic configuration, features, and examples of applications of MEICAP newly developed for the pitch control system of wind turbine generators.

2. Trends of Wind Power Generation in the World

Towards the goals of a low-carbon society and prevention of global warming, development of renewable energy resources such as photovoltaic power and wind power is being promoted around the world. In regard to wind power systems, there is a trend towards increasing power output capacity and the scale of wind firm is getting bigger while the installation locations are expanding from on-shore to off-shore sites. Given such a background, the market requires less labor for inspection and maintenance work for wind turbine systems. Further, regarding emergency power unit of pitch drive systems for wind turbine, there is a migration trend from lead-acid batteries to EDLC as EDLCs replacement frequency can drastically reduce exchanges since EDLCs expected operational lifetime is long. In addition, the pitch drive system is installed inside the hub which rotates with the blade pitch motor as required for the system. The space inside the hub is very limited and work there is difficult. As such, the smaller footprint and light mass of storage devices will improve working quality as well as reliability. European and other pitch drive systems have actively adopted capacitor-based power supply units for their pitch drive systems.

3. Advantages of the Introduction of EDLC

Voltage more than 200V is usually necessary to drive a motor turning a blade in the pitch drive system. On the other hand, the rating voltage of a lead-acid battery is low (12V) which makes it necessary to have a series connection and has problems with handling characteristics and connection operability. In addition, lead-acid batteries require replacement about every three years due to deterioration of performance characteristics. The replacement cost is a big burden on the project owner.

MEICAP has a long operational life and each element has a high rating voltage. If it is applied to a power supply unit with a pitch drive system in a wind turbine, you could get the following advantages compared to conventional lead-acid batteries and capacitors made by other firms.

(1) Lightweight of overall system and space saving
(2) Reduction of energy storage device maintenance frequencies
(3) Reduction of life cycle cost

4. Outlined Description of MEICAP 600S3 for Wind Turbines

The product development of MEICAP 600S3 type for pitch drive systems was made on the basis of conventional models (600S1 type). Table 1 shows the basic performance characteristics of the 600S3-74C consisting of 74 cells. Fig. 1 shows the external appearance of MEICAP.

The adoption of a bipolar multi-stack structure is the same as for other models. However, considering the severe operating conditions for wind turbine application, this model enhanced the conventional model in terms of safety, reliability, and durability. The 600S3 type has been intended to replace lead-acid batteries conventionally used as emergency power supplies for pitch control systems. Therefore, as for it, the market for the replacement of lead-acid battery for small UPS is expected too.

Table 1 MEICAP 600S3-74C Specifications

Compared with former models, rated voltage and electrostatic capacity were improved. The energy density was increased.

Type		600S3-74C (Developed item)	600S1-70C	600U1-70C
Rated voltage (continuous)		170V	160V	160V
Maximum voltage (peak)		185V	175V	175V
Capacitance		4.7F	4.5F	2.8F
Internal resistance (25℃)		0.78Ω	0.58Ω	0.34Ω
DC resistance (25℃)		0.34Ω	0.29Ω	0.24Ω
Maximum current (non-continuous)		100A	100A	100A
Mass		5.9kg	5.7kg	5.3kg
Size (Excluding embossed parts)	W	266mm	266mm	266mm
	L	316mm	316mm	316mm
	D	46mm	43mm	39mm
Operating temperature range		−25～+60℃	−25～+60℃	−25～+60℃

5. Improved Safety

Because an electrolyte solvent of the composition different from the conventional model was adopted, flammability and ignitability is minimized. The electrolyte solvent of MEICAP 600S3 is not combustible. Table 2 shows comparison of electrolyte performance characteristics.

Since the change to an electrolyte with low combustion characteristics, the safety level has been greatly improved. For example, MEICAP will not face serious malfunctions even if there is some difficulty in a system side fault such as overcharge by the charger malfunction or abnormal heating by the heater malfunction, etc.

As a result of a change in electrolyte solvent, this product was excluded from the category of flammable fluids under the United Nations Recommendations on the Transport of Dangerous Goods. Thus, this product is free from any regulatory restrictions in aircraft transportation. In fact, it can be transported as ordinary freight. In addition, MEICAP casing uses an exclusively designed metallic case. It improves durability against external shocks or contacts. It became very easy to handle. Fig. 2 shows an external view of MEICAP with the metallic enclosure.

Table 2 Comparison of Electrolyte Performance Characteristics

The electrolyte used for 600S3 has high boiling and flash temperatures, thus it is excluded from any regulatory restrictions relating to transportation.

	600S3 type electrolyte	600S1 type electrolyte
Boiling point	Approx. 240℃	Approx. 120℃
Flash point	Approx. 130℃	Approx. 40℃
Freezing point	Approx. −45℃	Approx. −45℃
Restrictions and category relating to transportation	Nil	Class 3 flammable fluid, Package Group II

Fig. 1 Electric Double Layer Capacitor, MEICAP

The 600S3 type for wind turbine has the same shape as that of a conventional Type 600. The standard product comes in 74-cell configuration.

Fig. 2 MEICAP with Metallic Enclosure

To meet the various installation conditions inside wind turbine hub, the MEICAPs are covered with a metallic enclosure to improve robustness and safety.

6. Application to Rotating Unit

According to the required function, the emergency power supply unit for the pitch drive system has to be installed near the pitch motor to ensure critical power during an emergency. In most wind turbine designs, this power supply unit is designed to be inside the rotating hub unit together with the blades and pitch motor. Fig. 3 shows structural drawing of wind turbine.

When installed inside the hub, the power supply block will be rotating when the blade faces the wind. For this reason, this product went through various endurance verification tests.

6.1 Hub Rotation Full-Scale Test

Fig. 4 shows the external appearance of the hub rotating condition full-scale test unit. This rotation full-scale has almost identical size of the actual hub diameter of the wind turbine. With this equipment, MEICAP can rotate under charging condition. We verified if this product faces any problem in voltage distribution and performance under various setup conditions and during the running period.

6.2 Long-Term Vibration Test

While rotating inside the hub, gravitation and centrifugal force are always being applied and the effect of repeated vibration is always at work while the blade is in rotation. Assuming the revolving speed of the hub at the maximum wind availability situation, a MEICAP installed inside the hub will tolerate 100 million vibration cycles at 100% wind availability. Therefore, we tested MEICAP unit in a vibration tester as shown in Fig. 5 and applied more than 100 million vibration cycles to the unit to check if there was any abnormality in characteristics.

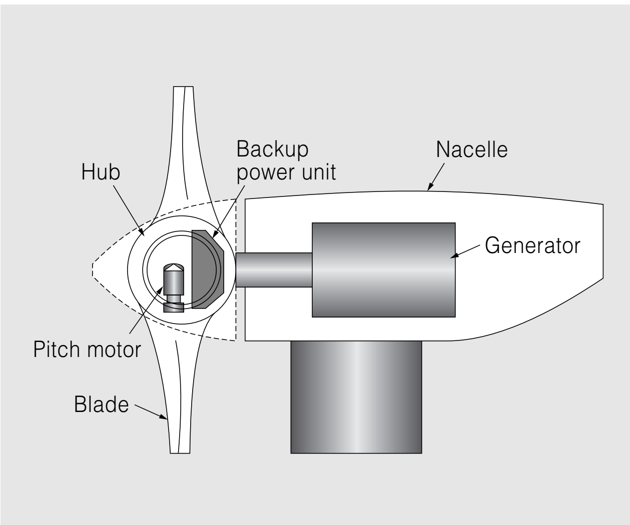

Fig. 3 Structural Drawing of Wind Turbine
A blade is attached to a hub of the nacelle tip and turns with a battery enclosure for pitch motors at the time of generation.

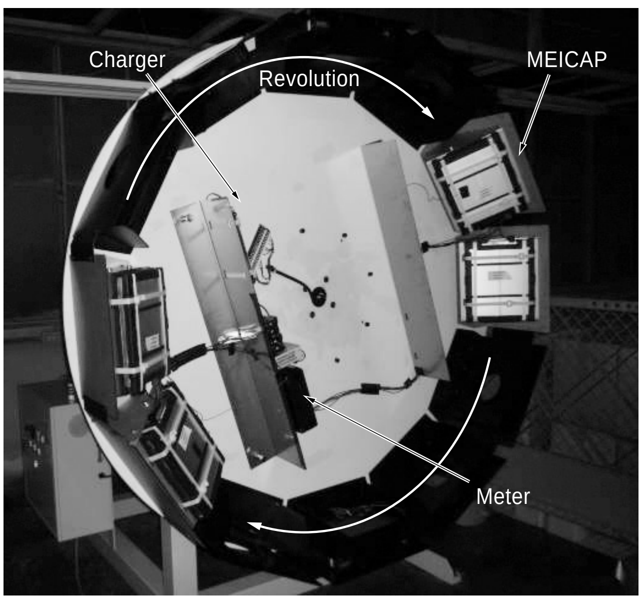

Fig. 4 Rotating Tester
Equipment which simulated the turn of the hub in an office performed various examinations without using a true wind turbine.

7. Field Test Using Real Wind Turbine

The field test situation is described below. The MEICAPs were put into real wind turbines.

7.1 Outline of Field Test

From June 2009 up to this time, verification test has been carried out at the Hachiryu Wind Farm in Mitane-cho, Akita Prefecture, Japan. Fig. 6 shows an overall view of the Hachiryu Wind Farm.

7.2 Test Details

Fig. 7 shows a single-line diagram of the pitch drive system. In the hub, a pitch motor power is supplied through a collector ring, and, at the time of the normal driving, the motor is driven by a grid power supply and controls the blade angle.

In case of grid power outage by any failure such

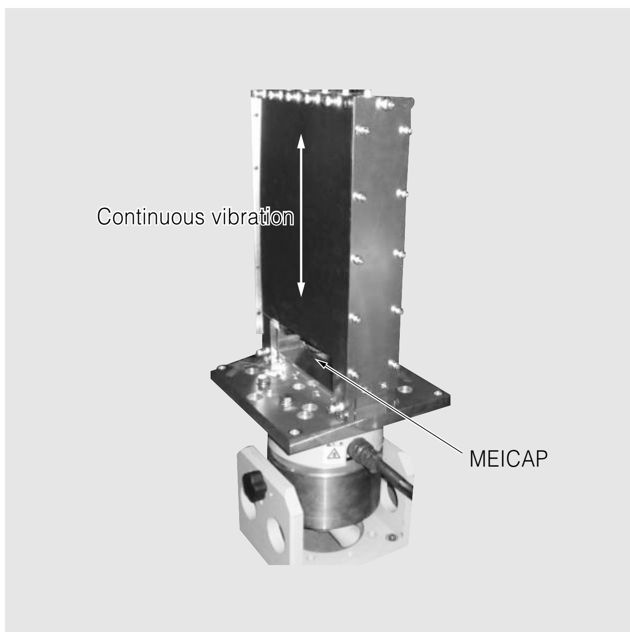

Fig. 5 Vibration Tester
In order to verify product durability against vibration caused by rotations, we introduced a special vibration tester. We conduct a long term continuous vibration test for more than 30 days.

Fig. 6 Overall View of the Hachiryu Wind Farm
At the Hachiryu Wind Farm, 17 units of 1.5MW wind turbine MD-77 are installed. MEICAPs have been tested in two wind turbines for demonstration test.

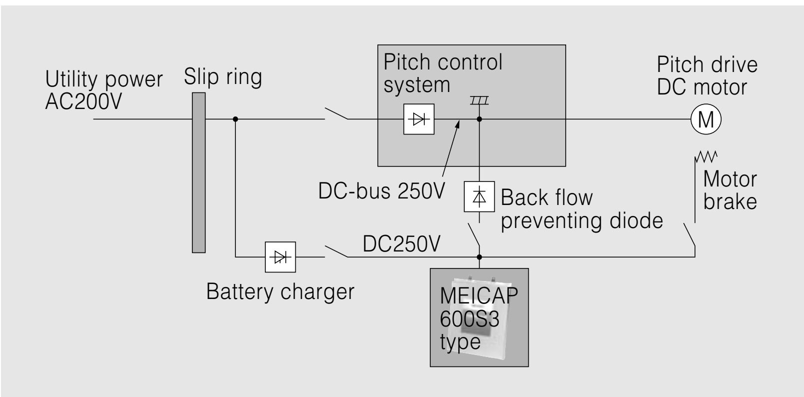

Fig. 7 Single-Line Connection Diagram of the Pitch Drive System
The pitch drives are normally powered by grid power transferred through a collector ring. In case of power outage by switching, MEICAP gives backup power to the pitch drives to turn the rotor blades to an out-of-wind position for safe shutdown.

Table 3 Specification of Capacitor for Field Test
The capacitor voltage was set at 250V so that it is adaptable to the battery charger voltage of the wind turbine. 58 stacks of MEICAP were arranged into a 2-series and 2-parallel configuration.

Capacitor type	600S3-58C
Configuration of capacitor connections	2-parallel and 2-series
Maximum charging voltage	250V
Capacitance	5.8F
Internal resistance	0.61Ω

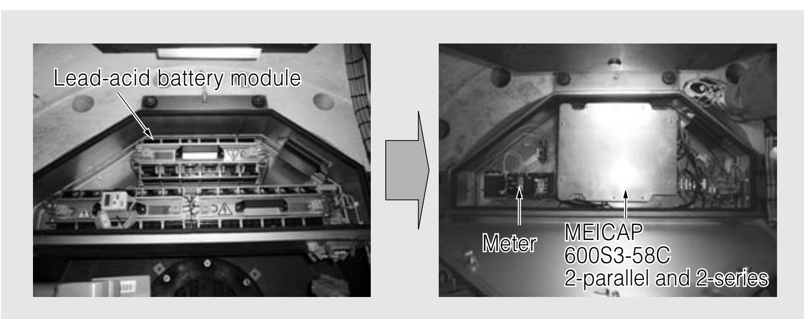

Fig. 8 MEICAP Installations
Existing lead-acid batteries were removed and MEICAP was installed in the backup power unit.

as disconnection from power transmission line or power apparatus damage by a lightning stroke, a pitch motor is driven by a saved power supply by the MEICAP and a blade is operated to the out-of-wind position for the safe shutdown of the wind turbine. In this case, MEICAP is switched to directly feed the power to the pitch motor.

7.3 MEICAP Specifications

During the field test, three axes of the respective turbine blades and existing lead-acid batteries were removed and replaced with MEICAP. Table 3 shows MEICAP specifications used in this system. To coordinate the system voltage, the number of stack cells was changed to 58 in two-series configuration to meet a maximum voltage of 250V. Fig. 8 shows the battery enclosure of the existing lead-acid batteries and MEICAP enclosure replacing the conventional battery. Since energy storage devices were replaced by MEICAP, the total weight of lead-acid batteries, 26kg, was reduced to 19kg.

7.4 Test Result

Fig. 9 shows in each axis the measured capacitor voltage and current when we conducted an emergency stop from the power generating condition and the blade-mechanism turned the rotor blade to the out-of wind position. According to difference in load at each axis, some difference was observed between the required pitch-control time and current. However, shutdown operation was completed within 12 seconds and no problem was confirmed in MEICAP performance.

Fig. 10 shows the state of EDLC voltage at typical axis which went through one year of testing. Occasionally, the EDLC voltage showed big voltage drops. This voltage drop is due to discharge as a result of starting the pitch motor.

By observing blade pitch performance under this test, we could confirm that MEICAP could work effectively as backup power and we could also confirm that there is no problem in adopting the MEICAP for the pitch drive system.

8. Future Trends

For MEICAP application to the pitch drive system for wind turbine, our challenge is to make MEICAP a genuine product for pitch drive system for overseas suppliers. In this regard, we will work hard to develop MEICAP's business for wind turbine application, especially for pitch drive system suppliers in Japan and throughout the world. Based on knowledge obtained from the field tests, we will promote a development program to improve the fitness of our

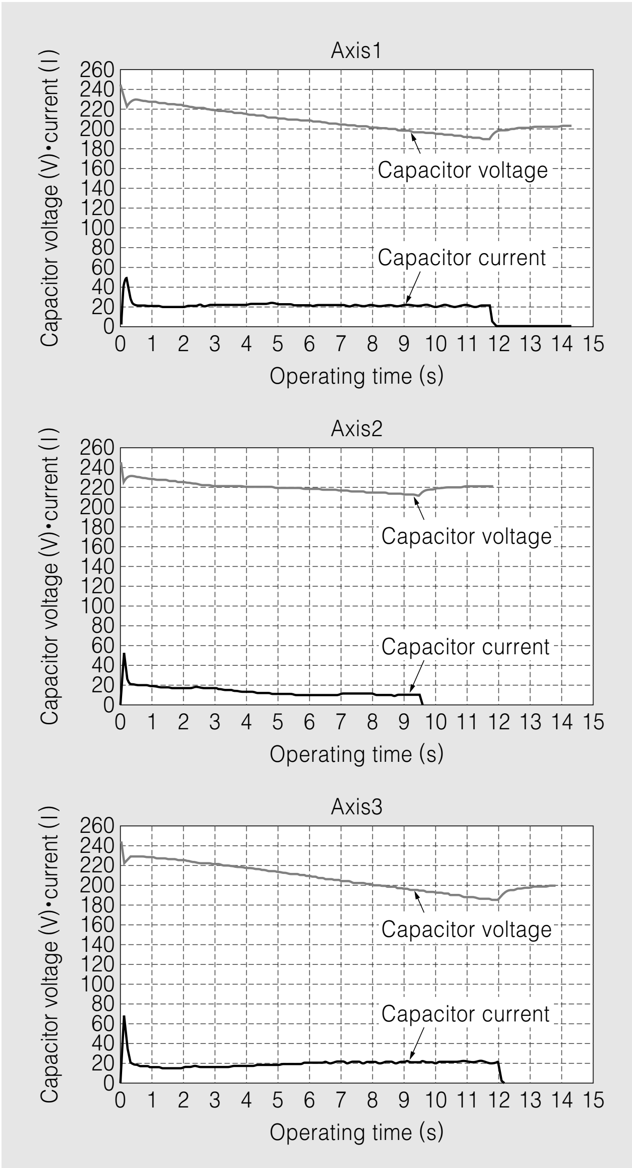

Fig. 9 Capacitor Discharge Data during the Pitch Control Time

The capacitor voltage and current are shown. This was when the rotor blade pitch angle was changed to an out-of-wind position by the pitch system for shutdown.

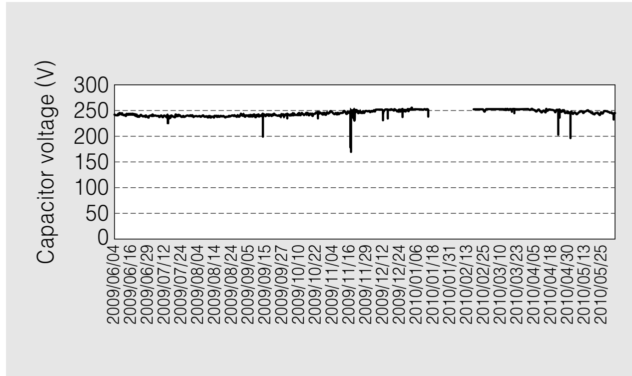

Fig. 10 Long-Term Field Test Data

The measured capacitor voltage is shown. The duration was for one year after the start of testing.

MEICAP to the pitch drive system for wind turbine generators.

9. Postscript

The Company will contribute to the growth of wind turbine business through its “Passion for Manufacturing Excellence” drawing on engineering and service experience through the wind firm operation business, servicing business, and wind turbine supply business as a sales agent.

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