Chapter 12
Japan

12.1 INTRODUCTION

After installation of a 20-MW wind farm in December 1999, Japan entered an age of commercial wind farms. At the end of 2002, the total wind-power capacity in Japan was estimated at 340 MW. The national wind target for the year 2010 is 3,000 MW, for which many efforts have been made. In April 2002, the Japanese government passed legislation for a Renewables Portfolio Standard (RPS).

12.2 NATIONAL POLICY

Strategy

At the United Nations (UN) Climate Change Conference in Kyoto in December 1997, the Japanese government agreed to reduce the output of greenhouse gases by 6% from 2008 to 2012, compared to the 1990 level. To attain this target, the government has changed the 2010 wind power target from 300 MW to 3,000 MW in the latest Primary Energy Supply Plan.

Progress Towards National Targets

In 1995, the government and the New Energy and Industrial Technology Development Organization (NEDO) started a promotional policy with subsidy programs. In June 1997, the Law on Special Measures for Promotion of Utilization of New Energy (New Energy Law) was enacted, which encouraged wind-generation businesses in Japan. As a result, some large-scale commercial wind farms, ranging from 20 MW to 30 MW, were developed, and a rapid increase in wind-power capacity in Japan was recorded in the last three years.

In April 2002, the Japanese government passed legislation for an RPS in order to realize the national target for renewables by 2010. The contribution of renewables to the

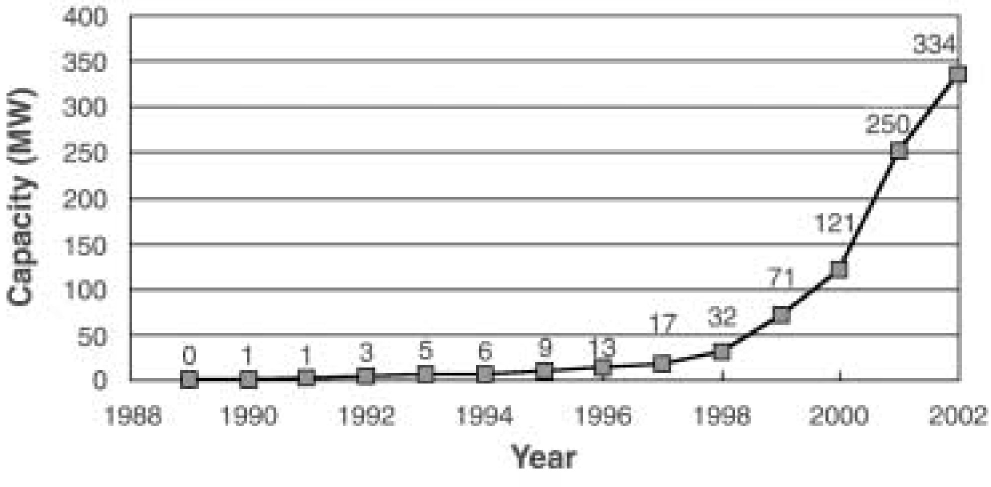


Figure 12.1 History of installed wind capacity in Japan

total primary energy resources will be 3% in 2010, up from 1.2% in 1999. Under the RPS, Japan's utilities are obligated to source 1.1% of their total electricity supply from renewables by 2010.

12.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

Japan's cumulative wind-power capacity was estimated at 334 MW at the end of 2002, according to NEDO. Figure 12.1 shows the history of wind turbine development in Japan.

Rates and Trends in Deployment

During the last four years, the increase in cumulative wind-power capacity was recorded as ten times. With support from government promotional subsidy programs, many commercial wind farms have been developed. However, there are some limitations on wind capacity due to grid problems indicated by some regional utilities where the purchase price is decided by tender.

Contribution to National Energy Demand

Wind-power generation from April 2001 to March 2002 was 348.2 GWh. The national energy demand in the same period was 963.3 TWh, and the contribution of wind power therefore counts for 0.036%. If the national target of 3,000 MW is realized, wind-power contribution to national primary energy resources will be 0.22%, since wind-power generation is equivalently evaluated as 1,340 ML of oil in the government scenario. (Wind Energy/New Energy = 1,340 ML/ 19,100 ML and New Energy/Total Primary Energy = 3.1%.)

12.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

NEDO has been conducting the following three subsidy programs as a part of the Ministry of Economic, Trade, and Industry (METI) introduction and dissemination program. These programs are playing an important role for local governments' and private companies' wind-power developments.

1. Field test program for developing wind turbine generating systems

This program started in 1995 to stimulate the introduction of wind energy plants into Japan. NEDO subsidizes local governments and private companies 100% for one year of wind measurements and 50% for facility construction and operation.

2. Regional new energy introduction program

This program has supported new energy projects developed by forefront developers or public sectors since 1998. NEDO subsidizes up to one-half for the design and construction of each wind-power plant with a capacity of more than 1,500 kW.

3. New energy business support program

This program is for private wind farm developers, and NEDO subsidizes up to one-third for each facility design and construction.

Unit Cost Reduction

More than 90% of the installed wind turbines in Japan are imported from Europe and the United States. Therefore, the unit cost is considered to be the same as in Europe or the United States. However, some other factors – such as transportation cost and the additional cost to stabilize the power for grid connection – require higher total plant cost.

12.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

The number of commercial wind farms has been increasing recently. Locations for large wind farms are concentrated in the northern part of Japan, which has induced some grid problems. More than 90% of the wind turbines employed in Japan are European or U.S. turbines. There are a few national manufacturers such as Mitsubishi Heavy Industries (MHI), Ltd. for large-scale wind turbines and Fuji Heavy Industries (FHI), Ltd. for small-scale wind turbines.

Operational Experience

In Japan, the technical issues related to wind power to be solved are related to power quality, typhoon attack, high turbulent intensity at hilly sites, and lightning strikes. Now, because many wind plants are located in rather complex terrain, siting techniques have become more important. For example, the capacity factor for Tappi Wind Park (owned by Tohoku Electric Power Co.) varies from 15% to 33% among units.

Main Constraints on Market Development

Grid capacity, or power quality, has become one of the most important issues in Japan. In the Hokkaido area, the available capacity for wind generation is limited by the regional utility to a maximum of 250 MW.

NEDO conducted two demonstration programs on power stabilization techniques and battery-back-up systems. Through these programs, huge amounts of technical data were gathered; however, the practical measures required to solve the grid capacity problem have not been drawn. Without solving this issue, the national target by 2010 might not be attained.

The problem of complex terrain also affects mechanical strength and electrical quality due to gusty and turbulent wind. It increases the cost of transportation, erection, and grid-connection. Lightening has recently become a significant problem because many turbines have been damaged by it.

12.6 ECONOMICS

As large-scale, commercial wind-power plants ranging from 20 MW to 30 MW are developed, the economics is getting more and more competitive. The cost of energy (COE) is 9.00 Yen/kWh to 11.00 Yen/kWh for medium-scale wind turbines with a capacity from 500 kW to 1,000 kW. The COE is 7.00 Yen/kWh to 9.00 Yen/kWh for large-scale wind farms comprised of wind turbines above 1,000 kW.

Trends in Investment

After installation of a 20-MW wind plant in October 2000, a 30-MW wind plant and several large wind plants over 10 MW have been newly developed or planned within the next few years.

The current wind turbine cost is approximately 100,000.00 Yen. The installation cost is decreasing as large-scale wind power plants increase. Cost can vary depending on wind condition, grid condition, and plant size. The plant cost is 130,000.00 Yen/kW to 200,000.00 Yen/kW for medium-scale wind turbines with capacities between 500 kW and 1,000 kW. The plant cost is 110,000.00 Yen/kW to 150,000.00 Yen/kW for large-scale wind farms comprised of large wind turbines with capacities higher than 1,000 kW.

	MWT-S2000
Rotor type	Horizontal axis, variable-pitch control, variable-speed control, gear-less type wind turbine
Rated power	2,000 kW
Rotor diameter	75 m
Hub height	60 m
Rotation	8 rpm to 24 rpm
Rated wind speed	13.0 m/s
Cut-in wind speed	2.5 m/s
Cut-out wind speed	25 m/s
Power control	Pitch control, AC/DC/AC
Generator type	Permanent magnet synchronous generator
Wind direction control	Yaw control

Table 12.1 Specifications for Mitsubishi's MWT-S2000 wind turbine

Trends in Unit Costs of Energy and Buy-Back Prices

The average electricity purchase price is about 18.00 Yen/kWh. The wind-generated electricity purchase price has been 11.50 Yen/kWh, according to the utilities' purchase menus. This is under the condition that the total capacity for wind generation at every regional network is limited by each regional utility, and the price is driven by tender. The purchase price is getting cheaper than 9.00 Yen/kWh.

12.7 INDUSTRY

Manufacturing

MHI is the only national manufacturer that supplies mid-sized to large-sized wind turbines. MHI recently developed variable-speed, synchronous wind turbines of 300 kW, 600 kW, and 2,000 kW. Recently, many MHI wind turbines have been constructed in the United States.

FHI is a new wind turbine manufacturer. Starting with 20-kW class rotor development in co-operation with the Mechanical Engineering Laboratory (MEL), FHI developed a 40-W Subaru wind turbine and a 100-kW wind turbine under a national project.

Industry Development and Structure

The major wind turbine manufacturers doing business in Japan are Neg-Micon, Vestas, Bonus, Enercon, MHI, and Lagerway. MHI developed a 2-MW machine and the first plant was erected in Okinawa in January 2003, as shown in Figure 12.2. The specifications for Mitsubishi's MWT-S2000 machine are shown in Table 12.1. It is a horizontal axis, variable-pitch control, variable-speed

Figure 12.2 Mitsubishi's MWT-S2000 wind turbine under construction at Gushikawa in Okinawa

control, gear-less type wind turbine with a permanent magnet synchronous generator.

Since 1 November 2000, Japan Natural Energy Company Ltd., has provided power generation services mainly to corporate customers using natural energy sources such as wind power with *Certification of Green Power*. Nearly 100 companies in the wind industry started the Japan Wind Power Association in 2002 and started communication.

Japan's manufacturer MHI has high export potential and shows business results all over the world, including such countries as the United States, the United Kingdom, Portugal, India, Mexico, and Germany.

12.8 GOVERNMENT-SPONSORED R,D&D

Priorities

Since 1978, the Japanese government – formerly the Ministry of International Trade and Industry (MITI), now METI – aims its wind energy Research and Development (R&D) program at energy security after the oil crises. This is one part of the general R&D program for renewable energy called the New Sunshine Project and has been directed by the New Sunshine Program Promotion (NSS) Headquarters, MITI. After global warming was recognized, the objective of the New Sunshine Project was set to develop innovative technology to create sustainable growth while solving both energy and environmental issues. In January 2001, the governmental ministries were reformed, and the NSS R&D activities were succeeded by METI in April 2001. In addition, MEL and the National Institute of Advanced Industrial Science and Technology (AIST) became independent research institutes. The national wind energy activities in Japan are shown in Table 12.2 and described in more detail below.

A. New Sunshine Project: Research, Development & Demonstration (R,D&D)
In 1999, Japan started new R,D&D programs on new wind technologies for remote islands as described in the section below, NSS-R,D&D Programs.

National Activities	Period	Organization/Institute
A. New Sunshine Project (R,D&D) (1) Wind Resources Measurement (2) R&D of LS Wind Turbines (500 kW) on Tappi Cape (3) Demonstration of a MW-class Wind Farm on Miyako Island (4) Generic, Innovative R&D (5) Advanced Wind Turbine Generating Systems for Remote Islands (6) Local Area Wind Energy Prediction Model	 1978- 1990-1994 1990-1997 1991-1998 1978- 1999-2003 1999-2003	 METI (NSS-HQ, MITI) NEDO NEDO, MHI, Tohoku EPC NEDO, Okinawa EPC AIST (MEL) NEDO NEDO
B. Demonstration Programs (1) Research on Stabilization of Output Power from Wind Turbine Generating Systems (2) Research on Stabilization of Output Power from Wind Turbine Generating Systems with Storage Batteries	2000-2001 2000-2001	NEDO NEDO
C. Promotion of Introduction (1) Field Test Program (2) New Energy Business Support	1992-	METI (MITI), NEDO
D. Standards (IEC, ISO, JIS)	1988-	METI, JEMA, AIST, Industries
E. IEA Wind R&D	1978-	METI, AIST, MU, JEMA

Table 12.2 National activities on wind energy

B. Demonstration Programs
In 2000 and 2001, two new demonstration programs were undertaken by NEDO to develop techniques to stabilize the output power from wind.

C. Promotion of Introduction
NEDO's Field Test Program, the New Energy Local Introduction Supporting Program, and the New Energy Business Supporting Program have played an important role in promoting the introduction of wind turbines among private sectors as well as local governments.

D. Standards
The national programs include co-operation in International Electrotechnical Commission (IEC) standard activities in the wind energy category. METI is also promoting the policy in order to maintain international consistency. In 1999, two Japanese Industrial Standards (JIS) that keep conformity with IEC 61400 standards were published, and in 2001, JIS had three more standards introduced.

E. IEA Wind R&D
NEDO, AIST (MEL), Mie University (MU), and the Japan Electrical Manufacturers' Association (JEMA) have participated in International Energy Agency (IEA) international co-operations in Tasks XI, XV, XVII, and XVIII by presenting technical data.

Table 12.3 shows the history of METI's budget for various wind energy activities.

NSS-R,D&D Programs

Since 1999, METI has conducted new R&D programs in order to meet the national target of 300 MW of wind power by 2010. Programs are needed partly because Japan has many severe external conditions such as typhoon attacks, high turbulence intensity, weak grids in remote areas and islands, and poor accessibility at hilly sites and islands. Three R&D projects are described below.

1. Advanced Wind Turbine Generating Systems for Remote Islands

Japan has plenty of wind resources, mostly on hundreds of islands where the electric power depends on expensive diesel power. NEDO has been conducting a national R&D project titled, Development of Advanced Wind Turbine Systems for Remote Islands, since 1999.

METI/NEDO developed a prototype, 100-kW turbine for remote islands where there may be severe external conditions such as typhoon attacks, high gusts, poor accessibility, lack of large cranes, and weak grids.

The targets of this project are as follows.

• Competitive COE less than 20.00 Yen/kWh: Among small islands, the COE of wind can be cheaper than that of diesel, amounting to 30.00 Yen/kWh to 100.00 YenkWh.

• High penetration up to 40%: Demonstrations are intended to show that design power quality is maintained at a maximum of 40%.

• Easy construction and maintenance: On islands where large cranes are not available, turbines can be easily constructed using a 16-ton crane and a gin pole unit (See Figure 12.4).

• Design extreme wind speed of 80 m/s: Turbines are designed safe for up to 80 m/s of extreme wind speed under typhoon attacks.

Figure 12.3 shows two units of the 100-kW prototypes, erected on Izena Island in 2002. Table 12.4 shows main design features. The annual wind speed at the site is approximately 6 m/s, which is typical; however, the island is located under the main pass of typhoons. The island is supplied with electric power from five diesel generators with a total capacity of 3,800 kW.

YEAR	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
NSS Project (R,D&D)	540	981	978	744	634	606	554	477	414	516	739	722
NEDO Subsidies (Field Test)	-	-	-	-	80	320	460	1,529	1,739	1,620	1,390	460
NEDO Subsidies (Business Support, etc.)	-	-	-	-	-	-	430	1,670	3,320	11,010	18,850	11,810
NEDO Power Stabilization Demonstration	-	-	-	-	-	-	-	-	-	2,070	910	300
Total	540	981	978	744	714	926	1,444	3,676	5,473	15,216	21,889	13,292
Ratio of R&D (%)	100	100	100	100	88.8	65.4	38.4	13.0	7.6	4.7	2.6	5.4
Ratio of Subsidy (%)	0	0	0		11.2	34.6	61.6	87.0	92.4	95.3	97.4	94.6

(Source: NEDO)

Table 12.3 Budget for national wind energy projects in millions (Yen)

Figure 12.3 100-kW prototypes on Izena Island in Okinawa Area

As outlined in Table 12.5, the program will close in March 2003 after the completion of grid-connected operations that demonstrate a maximum of 40% penetration.

2. Local Area Wind Energy Prediction Model

This computational fluid dynamics (CFD) model is applied to Japanese complex terrains with high accuracy in predicting local wind flows. Figure 12.5 shows the nesting structure employed in the CFD model. Flow models employed in each nesting domain are shown in Figure 12.6, and Figure 12.7 shows the performance of the developed CFD model.

3. CFD Aerodynamics of Airfoil Sections

Generic research conducted by AIST shows that the operational characteristics of a wind turbine are highly affected by varying wind conditions. These conditions bring direct effects on the airfoil performance of the rotor blade because the angle of attack and Reynolds number vary widely, and flow separation occurs often. CFD research has been focused on simulating the flow field around an airfoil section to study the structure of a stall or formation of a separation

Design Items	Specifications
Rated power	100 kW
Rotor type	Horizontal Axis Upwind
Rotor diameter	22 m
Hub height	24 m
Number of blades	3
Blade length	10.5 m
Cut-in wind speed	3.0 m/s (10-min average)
Rated wind speed	10.5 m/s
Cut-out wind speed	25.0 m/s (10-min average)
Extreme wind speed	80 m/s (instant)
Power control	Active pitch
Rotor speed	30 rpm to 72 rpm
Yaw control	Active yaw
Main brake	Blade feather
Main brake	Feather
Second brake	Feather (Fail safe)
Generator	PMG (60 pole)
Construction	Jim pole type
Lifetime	20 years
Manufacturer	Fuji Heavy Industries, Ltd.

Table 12.4 Main technical specifications of a 100-kW wind turbine for remote islands

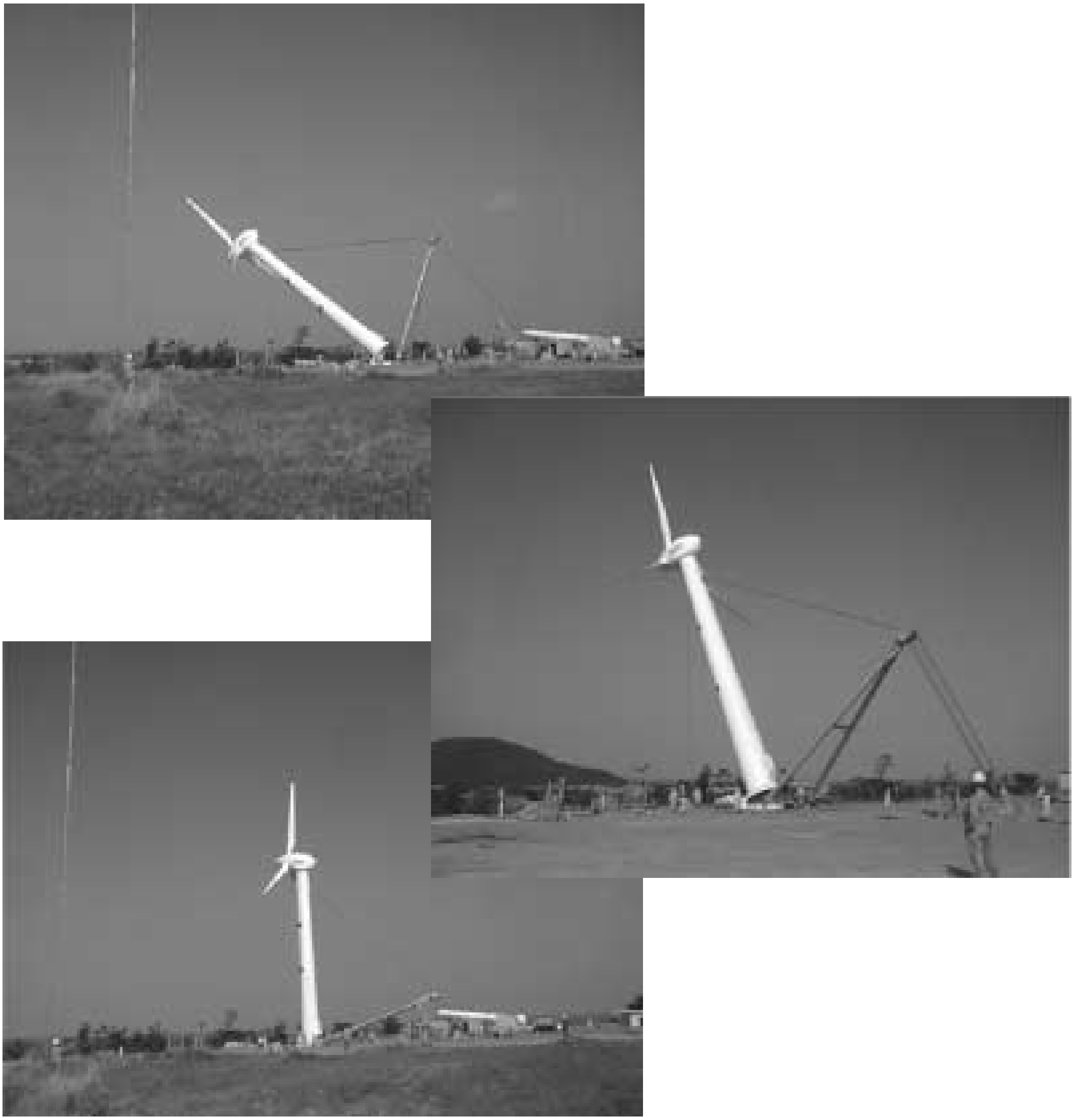


Figure 12.4 Construction with a gin pole unit

Financial Year	Main Items
1999	Conceptual Design
2000	Detail Design, Component Tests
2001	Manufacturing, Construction
2002	Demonstration, 40%-Penetration Tests, etc.

Table 12.5 Testing schedules for the R&D Project of Advanced Wind Turbine Generating Systems for Remote Islands

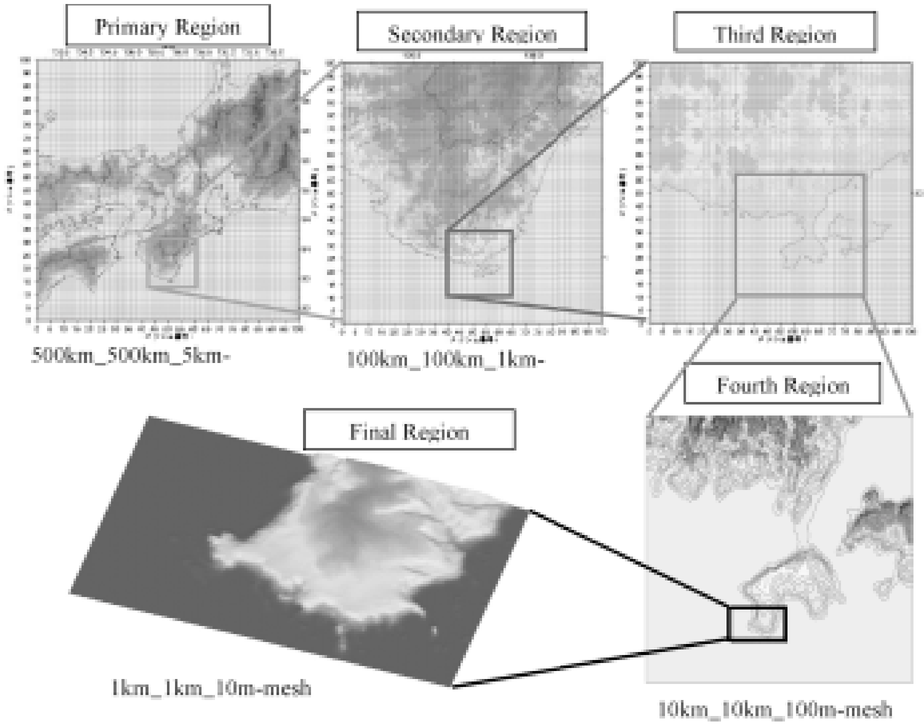
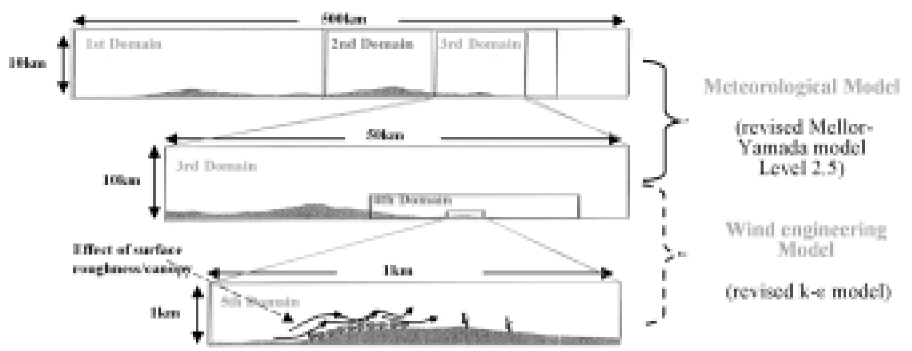


Figure 12.5 Nesting structure of the CFD model



(1st Domain) horizontal area: 500km, **horizontal resolution: 5km**, vertical area: 10km
(2nd Domain) horizontal area: 100km, **horizontal resolution: 1km**, vertical area: 10km
(3rd Domain) horizontal area: 50km, **horizontal resolution: 500m**, vertical area: 10km
(4th Domain) horizontal area: 10 km, **horizontal resolution: 100m**, vertical area: 4km
(5th Domain) horizontal area: 1km, **horizontal resolution: 10m**, vertical area: 1km

Figure 12.6 Flow models in each nesting domain

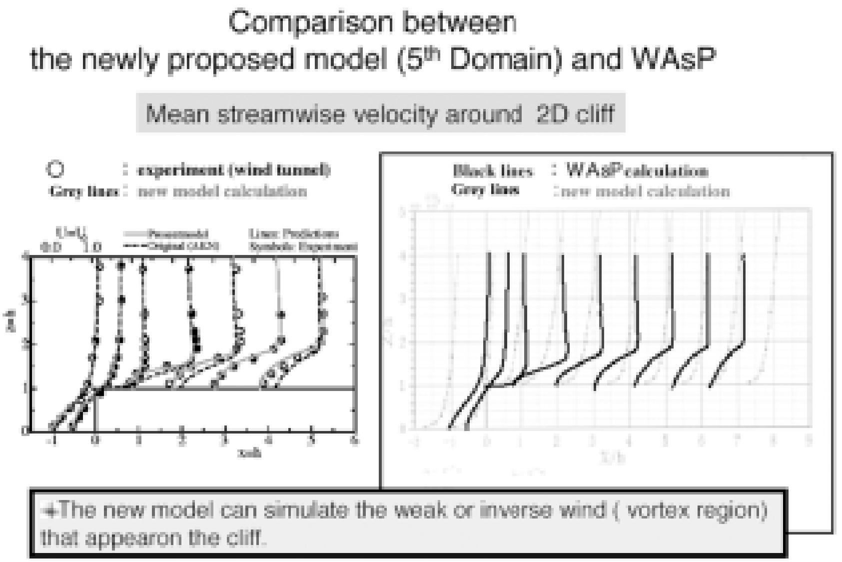


Figure 12.7 Performance of the developed CFD model

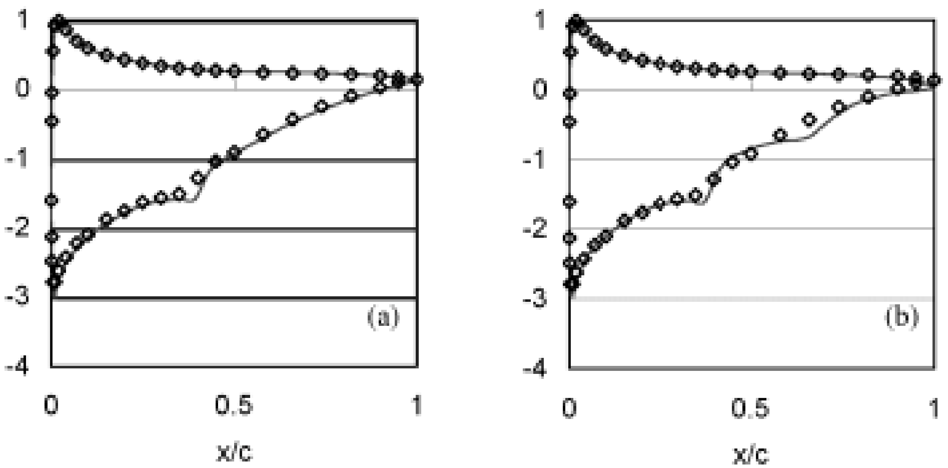


Figure 12.8 A sample of a separation bubble simulation using CFD

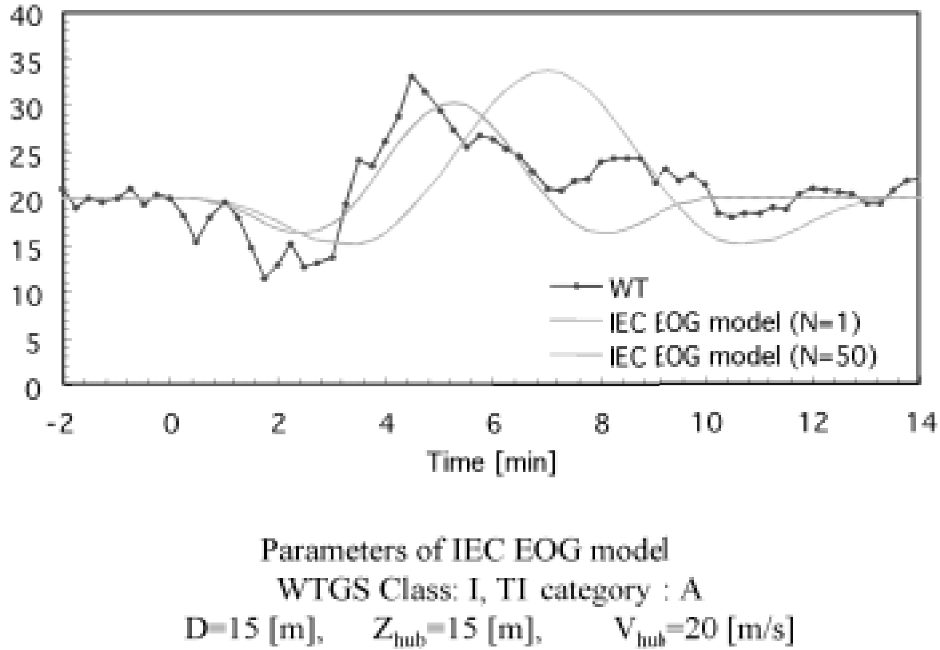


Figure 12.9 An observed high gust compared to IEC EOG models

bubble. Some fine flow simulations were successfully performed by means of solvers for the Navier-Stokes equation using the QUICK scheme and LES. The primary technical conclusions are that 3-D analysis is essential, and CFD may provide advanced tools as a numerical wind tunnel in the near future.

Field testing of a 15-kW, variable-speed research turbine with a diameter of 15m and a teetering rotor at Mt. Nonobo (a typical hilly and gusty site in Japan) has provided valuable technical data. Figure 12.9 shows an observed high gust compared to IEC EOG models.

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