The Total Commercialization Solutions for Floating Offshore Wind Power

2018. 6. 22

Lee J.Y., Noh M.H., Kim E.S. and Na S.K.

☐ Comparison of site characteristics

Site	**On-shore**	**Fixed (Shallow water)**	**Floating (Deep water)**
Water depth	-	~50m	~300m(Up to 900m)
Turbine (MW)	1~2MW	3~5MW	5~10MW(Current state Max.)
Wind speed	4~8m/s(23%)	8~12m/s(40%)	
Min. Wind Farm	15MW	100~300MW	300~500MW
Platform type	Anchored Fixed type	Mono/Tri-Pile, Tri-pod, Jacket	Floating Platform
CAPEX	$2M/MW	$5M/MW	$6~9M/MW
Technical needs	• Transportation & Installation	• CAPEX(EPC) cost reduction technology	• CAPEX & OPEX Cost reduction technology(EPC & O&M)
Business envirorment	• Larger wind turbine, Site approroval & Permits	• Good to Large size wind farm • Residents` approval & Permit • Installation / O&M cost	• High capacity turbine • Minimized Environmental problem, Residents` approval • Huge initial investment

□ LCOE estimation

$$\text{LCOE}=\frac{Lifetime\ expenses\ for\ capital+financing+installation+O\&M+Miscellaneous}{Lifetime\ energy\ production}$$

※ Solution Marketing

Infrastructure

Customer Value

Customer product development

Before & After service

Co-Investment (JV, loan)

POSCO's Infrastructure of Solution Marketing

R&D	Service	Biz. Support
PAC	GTC, TSC	Downstream Biz
Pilot Plant	Mobile Service System	POSCO Capital

□ Demonstrate projects for FOWT(Key player: NOR≥Japan≥USA)

Type							
Project / First Operation	Karmøy(NOR)	Aguçadoura(Po)	**Fukushima(JP)**			Sakiyama(JP)	Kitakyushu(JP)
	2009	2011	2013	2015	2016	2015	2019
Model	HyWind	WindFloat	OC4(Mirai)	Shinpoo(新風)	Hamakaze/Kizna	Kyoto Univ.	FloatGen(Ideol)
Developer	Statoil	EDP/PPI	Mitsui	Mitsubishi	Hitachi Zosen/JMU	Toda SPC	Hitachi Zosen
Float type	Spar	Semi-sub (column)	Semi-sub (column)	Semi-sub (pontoon)	Advanced spar	Hybrid Spar	Moon–pool
Capacity	2.3MW Siemens	2MW Vestas	2MW Hitachi	7MW → 9MW AAN(MHI)	5.2MW Hitachi	2MW Subaru	3MW/5.2MW Gamesa/Hitachi
Mooring line	3	4	3	4	8(6)	3	9 / 12
Weight	1,200	1,300	2,300	**12,000**	3,600	1,200	3,100/
2nd project	Scottland 6MW X 5unit	Setubal 6~8MW X 4unit	Fukushima 5.2MW X 3unit	8MW calss WTG (planning)		Grid connected	2.7~5.6GW (~2030)

☐ Various platforms of NEDO (2 Fixed Sub-structure & 6 Floating Model)

Near shore | **Fixed type Shallow water** | **Floating type**

Kamisu (2003~2010)	Hibikinada (2010~2012)	Choshi (2010~2012)	GOTO (2013)	SKWID (2013.04)	Fukushima (2013~2019)
Mono Pile type DownWind type FHI(Subaru):2MW*7	Hybrid Gravity J-Power team JSW: 2MW	Gravity PC TEPCO MHI: 2.4MW	Spar type Kyoto Univ. FHI(Subaru): 2MW	Savonius/Darrieus Buoyancy stabilized MODEC: 1MW	Semi-submersible DownWind Hitachi: 2MW

Hibikinada Pjt.
Hitachi Zosen

MHI: 7MW

Sakata, Tohoku (10 MW)
2004: 10MW (2MW x 5)

Kitakyushu, Kyushu
(2 MW)
2013: 2MW (2MW x 1)

Kamisu, Kanto (30 MW)
2010: 14MW (2MW x 7)
2013: 16MW (2MW x 8)

Choshi, Kanto (2.4 MW)
2013: 2.4MW (2.4MW x 1)

※Hybrid solution
1) Optimization (Water depth/Typhoon/Soil/Cost)
2) Global market strategy

□ "Fukushima Forward Pjt."

Fukushima Floating Offshore Wind Farm Demonstration Project

•JMU: Japan Marine United
•MES: Mitsui E&S Shipbuilding
•MHI: Mitsubishi Heavy Industry

Facility Name	Scale	Wind Turbine Form	Floating Form	Project Term	Fields
Floating Substation "**Kizuna**"(인연)	25MVA **66kV**	Substation	Advanced Spar (JMU)	1st (2013)	
Floating Wind Turbine "**Mirai**"(미래)	2MW	Downwind-Type (**Hitachi**)	4 Column Semi-Sub (MES)	1st (2013) (가동율: 29%)	
Large Floating Wind Turbine "**Shinpuu**"(신풍)	7MW	Oil Pressure Drive-Type (**MHI**)	3 Column Semi-Sub (MHI)	**2nd** (2015)	
Large Floating Wind Turbine "**Hamakaze**"(갯바람)	5.2MW	Downwind-Type (**Hitachi**)	Advanced Spar (JMU)	**2nd** (2016)	

☐ Fukushima Forward Pjt. Hamakaze(5.2MW) Installation

○ Demonstrating O&M cost reduction technology after Hmakaze

○ Specification:
- Turbine: Down-wind Hitachi 5.2MW(Hub-height: 86m, Extreme wind: 55m/s, Rotor dia.: 127m, Pitch angle: -8°)
- Floating structure type: Advanced spar
- Overall structure : Height: 119.4m, Draught: 33m, Weight: 3,600ton, Wide: 51 meters,
- Installation: Yoshida Gumi, Mooring line: 6 Line, Steel grade: AH32

Source: Hitachi Review Vol. 66, No. 5 468–469

☐ Hibikinada(Kitakyushu) demonstrate Pjt.

○ New type offshore wind platform(FloatGen) for shallow water(50m) and low cost will be demonstrated

○ Specification:
- Turbine: Up-wind type 3MW class(Aerodyn's SCDnezzy)
- Floating structure type: Semi-sub(Moon pool or Damping pool) type
- Overall structure : Height: 10m, Draught: 7.5m, Wide/Length: 51 meters, Weight: 3,100 ton(`18.6.8)
- Fabricater: Hitachi-zosen, Mooring line: 9 Line, Steel grade: AH32

Source: NEDO & Hitachi zosen

□ Technological competition

☐ History and expected future deployments of floating wind technologies

Source: Offshore Wind Farm Subscription, Market Overview Report, 4C Offshore October 2017

□ “Mirai” Design basis & Specification

○ Unmanned Remote monitoring (SCADA, alarm, acceleration, inclination and strains)
○ Rule: Class NK Guide Line「Guide line for floater with wind turbine」
○ Design life: 20 years Fatigue、Painting(N사)、Corrosion
○ Environmental design conditions
- Design Water depth: 120m
- Wind: 48.3m/s at hub height
- Wave: 11.7m, Significant wave height
- Current: 1.5m/s
- Tsunami: 0.87m/s (horizontal velocity)

○ **Wind Turbine: 250MT**
- Down Wind HWT 2.0-80(Rotor D.: 80.0m)

○ **Floater**
- Length: 57.5m
- Width: 64.23m
- Depth: 32.0m
- Draft: 16.0m

○ **Mooring**
- Catenary(60°*6Line)
- Chain: Ø132mm
- Anchor: High hold capacity drag anchor

☐ Fabrications “Mirai” Parts

Reference: 8th ASEF Jeju, Korea(Mitsui Zosen, Japan) & PPI(USA)

☐ Fabrications (MIRAI vs. WindFloat)

Reference: 8th ASEF Jeju, Korea(Mitsui Zosen, Japan) & PPI(USA)

☐ Assembling & Dock-out

☐ Wet Towing(Chiba → Onahama Port)

☐ Mooring & Anchoring(Shimizu Const., NSSMC Eng. SSE JV)

☐ Mooring Proof Load Test & Power cable to J-Tube(Furukawa Electric)

☐ Structures(Floater)

☐ Structural soundness monitoring system

□ MES-S`s 2MW class “MIRAI”

□ MHI`s 7MW class “SHINPU”

☐ Rising O&M cost due to technical problem

○ Fair Lead-Mooring Damage Conditions Assessment

○ OPB(Out-of Plane Bending) Fatigue Performance Evaluation (Referred to Prof. Jung, Joon-Mo, Inha Univ.)

Fatigue (Transocean Spitsbergen 2012, Transocean Leader 2011, Norne 2012)

OPB Fatigue Induced Fracture Mode

Heavy Narrow Wear (OTC 20613)

☐ Core technology

- ○ Fluid-structure interaction analysis & Floater/Mooring coupled analysis
- ○ Structural performance improvement solutions based on hign performance steel
- ○ Advanced materials(Steel) & Welding technology

Load case | **Pre-FEED** (Hydrostatic stability → Dynamic → Mooring → Structure) | **FEED/Fabrication**

Wind/Wave/Current | Hydro-static | Hydro-dynamic analysis | Structure/Fatigue | Detail design & Fabrication

Material | **Installation & Maintenance**

Anti-corrosion steel | Long-life coating | Low-cost & High fatigue performance | Load-out & Towing

☐ 2018 REC(Renewable Energy Certificate) Weight revision(`18.5.24)

Source: Ministry of Trade, Industry and Energy(2018.5)

Energy source	REC weight	Appclicable energy source and requirement	
		Installation type	Specification
Solar photovoltanic energy	1.2	On general site	Under 100kw
	1.0		Above 100kW
	0.7		Above 3,000kW
	0.7~1.2 → 0.7	On field	-
	1.5	Re-using existing facility	Under 3,000kW
	1.0		Above 3,000kW
	1.5	On floating	
	1.0	Non-utility generation for grid connected	
	5.0	ESS (Connected to solar powered generation)	2018, 2019
	4.0(20 Year)		2020
Renewable energy	1.0 → 0.25	IGCC, Syngas, Waste energy and Bio-SRF	
	0.5	Landfill gas, Wood pellet and Wood chip	
	1.0	Hydroelectric, onshore wind power, tidal power(with seawall), and bio-energy (Bio diesel, bio gas, etc.)	
	1.0~2.5	Geothermal power and tidal power(without seawall)	
	1.5	Hydrothermal generation and unused biomass multi-fuel generation	
	2.0	Fuel cell, tidal power and unsed biomass (only for bio-energy facility)	
	1.5 → 2.0	Offshore wind power	Less than 5km
	2.0 → 2.5		From 5km to 10km
	2.0 → 3.0		From 10km to 15km
	2.0 → 3.5		Longer than 15km
	4.5	ESS (Connected to wind powered generation)	2018, 2019
	4.0(20 Year)		2020