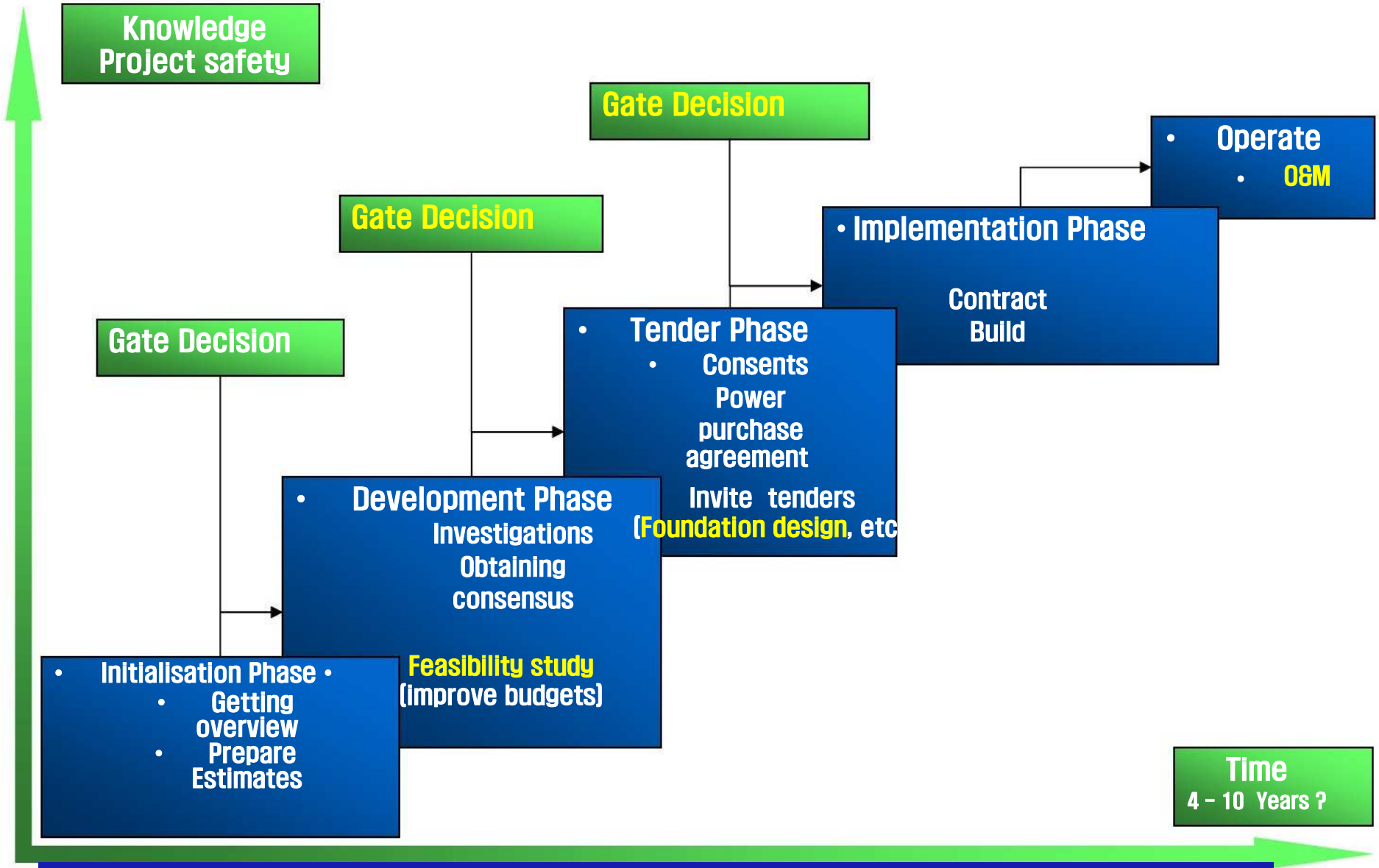
A development of Floating Lidar System

2018. 06. 22. Symposium on Wind Energy

Namho Kyong
Wind Energy Research Laboratory, KIER

Developing offshore wind farm, Metocean data is indispensable



Yellow character part needs offshore measurement

Feasibility study

Project:
Jaeun

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Korea Institute of Energy Research
71-2 JANG-DONG YUSONG-GU
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Calculated:
2017-11-21 오후 8:49

Meteo data report - Main results

Mast: Default Meteo data description (1); Jaeun
Mast position: UTM WGS84 Zone: 52 East: 226,493 North: 3,864,269

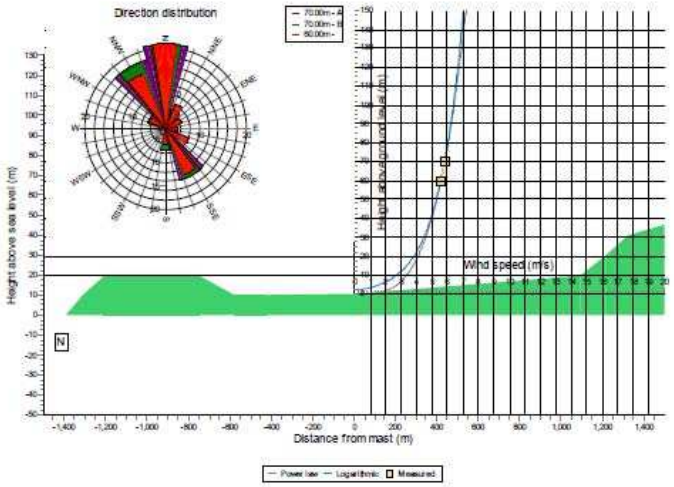
Measurement heights and wind speeds (in this report)
Disabled data not included in overview table below

ID	Height [m]	Data recovery [%]	Records	U_max [m/s]	U_mean *) [m/s]
70.00m - A	70.00	100.0	52560	23.0	5.8
70.00m - B	70.00	100.0	52560	23.4	5.8
60.00m -	60.00	100.0	52560	22.8	5.5

Scale: 50,000

*) U_mean is simple arithmetic average

Mean wind profile for all concurrent data and terrain profile for the most frequent sector of height: 70.00m - A: N (left side)



Profile characteristics for best curve fit through all data (Note: Values are only fully valid in flat terrain)
Shear exponent 0.2790 (Power law profile)
Roughness lenght 1.7974 m class 4.09 (Equivalent roughness for logarithmic profile)

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Calculated:
2017-11-21 오후 8:28/3.1.597

PARK - Main Result

Calculation: Jaeun wind farm
Wake Model N.O. Jensen (RISØ/EMD)

Calculation Settings
Air density calculation mode Individual per WTG
Result for WTG at hub altitude 1.222 kg/m³ to 1.225 kg/m³
Air density relative to standard 99.7 % to 100.0 %
Hub altitude above sea level (asl) 91.9 m to 120.8 m
Annual mean temperature at hub alt. 13.0 °C to 13.1 °C
Pressure at WTGs 1,003.5 hPa to 1,007.0 hPa

Wake Model Parameters
Wake decay constant 0.075 Open farmland

Displacement heights from objects

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0.5	360.0	1.0	0.5	30.5	1.0

Scale 1:75,000
New WTG
Meteorological Data

Key results for height 70.0 m above ground level

Terrain UTM WGS84 Zone: 52

	X(East)	Y(North)	Name of wind distribution	Height [m]	Type	Wind energy [kWh/m²]	Mean wind speed [m/s]
A	226,493	3,864,269	Default Meteo data description (1)	70.0	MEASURE	2,432	5.8

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	Result-10.0% [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Park efficiency [%]	Specific results=) Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	99,495.7	89,546.2	107,512.1	92.5	25.8	8,140.6	2,261	6.0

=) Based on Result-10.0%

Calculated Annual Energy for each of 11 new WTGs with total 39.6 MW rated power

	WTG type Links	Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh]	Result-10.0% [MWh]	Park Efficiency [%]	Free mean wind speed [m/s]
1	A	Yes	Siemens	SWT-3.6-130-3,600	3,600	130.0	85.0	EMD	Level 0 - Calculated - Std. 106dB - 04-2016	8,661.5	7,795	88.60	6.05
2	A	Yes	Siemens	SWT-3.6-130-3,600	3,600	130.0	85.0	EMD	Level 0 - Calculated - Std. 106dB - 04-2016	8,478.2	7,630	86.72	6.05
3	A	Yes	Siemens	SWT-3.6-130-3,600	3,600	130.0	85.0	EMD	Level 0 - Calculated - Std. 106dB - 04-2016	9,217.4	8,296	94.28	6.05
4	A	Yes	Siemens	SWT-3.6-130-3,600	3,600	130.0	85.0	EMD	Level 0 - Calculated - Std. 106dB - 04-2016	8,838.7	7,955	90.41	6.05
5	A	Yes	Siemens	SWT-3.6-130-3,600	3,600	130.0	85.0	EMD	Level 0 - Calculated - Std. 106dB - 04-2016	9,516.3	8,565	97.34	6.05
6	A	Yes	Siemens	SWT-3.6-130-3,600	3,600	130.0	85.0	EMD	Level 0 - Calculated - Std. 106dB - 04-2016	8,806.3	7,926	90.20	6.05
7	A	Yes	Siemens	SWT-3.6-130-3,600	3,600	130.0	85.0	EMD	Level 0 - Calculated - Std. 106dB - 04-2016	9,076.1	8,168	92.84	6.05
8	A	Yes	Siemens	SWT-3.6-130-3,600	3,600	130.0	85.0	EMD	Level 0 - Calculated - Std. 106dB - 04-2016	9,374.5	8,437	95.89	6.05
9	A	Yes	Siemens	SWT-3.6-130-3,600	3,600	130.0	85.0	EMD	Level 0 - Calculated - Std. 106dB - 04-2016	9,106.1	8,195	93.29	6.05
10	A	Yes	Siemens	SWT-3.6-130-3,600	3,600	130.0	85.0	EMD	Level 0 - Calculated - Std. 106dB - 04-2016	9,090.0	8,181	92.98	6.05
11	A	Yes	Siemens	SWT-3.6-130-3,600	3,600	130.0	85.0	EMD	Level 0 - Calculated - Std. 106dB - 04-2016	9,330.6	8,398	95.44	6.05

WTG siting

UTM WGS84 Zone: 52

		X(East)	Y(North)	Z [m]	Row data/Description
1	New	227,846	3,865,363	9.3	Siemens SWT-3.6-130 3600 130.0 IOI hub: 85.0 m (TOT: 150.0 m) (151)
2	New	227,648	3,865,814	10.0	Siemens SWT-3.6-130 3600 130.0 IOI hub: 85.0 m (TOT: 150.0 m) (152)
3	New	227,769	3,866,077	10.0	Siemens SWT-3.6-130 3600 130.0 IOI hub: 85.0 m (TOT: 150.0 m) (153)
4	New	227,132	3,865,539	18.1	Siemens SWT-3.6-130 3600 130.0 IOI hub: 85.0 m (TOT: 150.0 m) (154)
5	New	226,836	3,865,287	19.5	Siemens SWT-3.6-130 3600 130.0 IOI hub: 85.0 m (TOT: 150.0 m) (155)

To be continued on next page...

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Foundation design

1. Offshore foundation design needs huge amount of calculation for load case due to anisotropy of jacket
2. Simultaneous wind and wave char. are crucial

Element Number	Node Number	Node ID	Inverse SN slope	Mx [kNm]	My [kNm]	Mz [kNm]	Fx [kN]	Fy [kN]	Fz [kN]
100	100	Mbr 1 End 1	3	594.86	2839.08	2649.76	60.57	90.11	98.55
			4	687.36	3562.23	2931.60	70.97	103.77	112.03
			5	787.32	4280.13	3246.39	80.84	117.95	125.72
100	101	Mbr 1 End 2	3	591.61	2695.97	2501.75	60.49	85.59	93.97
			4	684.01	3380.13	2762.28	70.89	98.28	106.93
			5	783.85	4059.71	3055.31	80.75	111.50	120.14
101	101	Mbr 2 End 1	3	591.61	2695.97	2501.75	60.49	85.59	93.97
			4	684.00	3380.13	2762.28	70.89	98.28	106.94
			5	783.85	4059.71	3055.31	80.75	111.50	120.14
101	102	Mbr 2 End 2	3	589.54	2588.45	2391.27	60.44	81.97	90.22
			4	681.91	3238.81	2636.96	70.83	93.89	102.81
			5	781.73	3885.80	2914.66	80.67	106.35	115.68
113	113	Mbr 14 End 1	3	572.76	1768.82	1430.24	59.89	49.70	53.01
			4	664.53	2057.60	1568.53	70.24	54.56	66.08
			5	763.56	2363.27	1732.66	80.04	60.01	79.23
113	114	Mbr 14 End 2	3	571.73	1706.09	1349.58	59.84	48.73	51.69
			4	663.47	1972.73	1480.89	70.19	53.37	64.75
			5	762.47	2256.11	1636.91	79.98	58.62	77.80
126	126	Mbr 27 End 1	3	563.76	822.92	371.62	59.37	46.44	51.57
			4	655.35	934.19	423.85	69.69	51.07	60.83
			5	754.12	1051.39	481.60	79.44	56.47	70.61
126	127	Mbr 27 End 2	3	563.54	791.64	345.25	59.35	46.01	51.17
			4	655.13	900.10	395.24	69.67	50.63	60.35
			5	753.92	1014.17	449.94	79.42	56.02	70.06

Table 1b: Damage equivalent loads: Tower

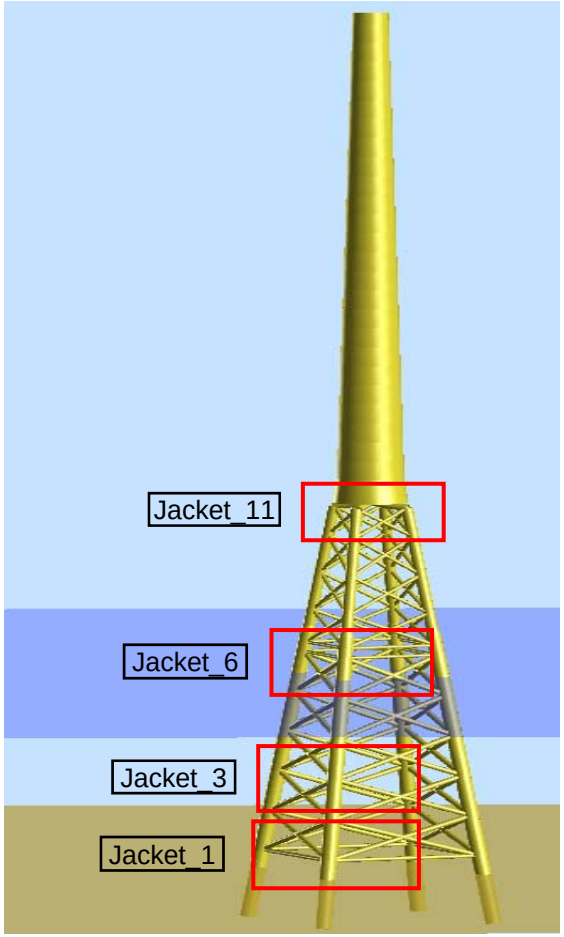


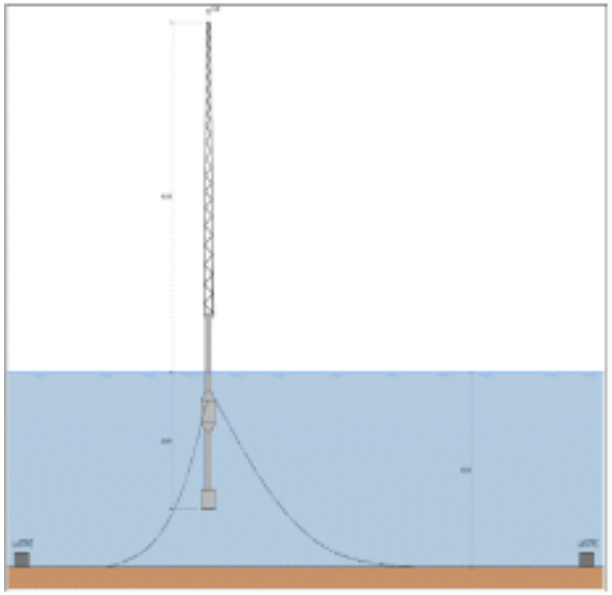
Figure 1b: Orientation of support structure to wind direction

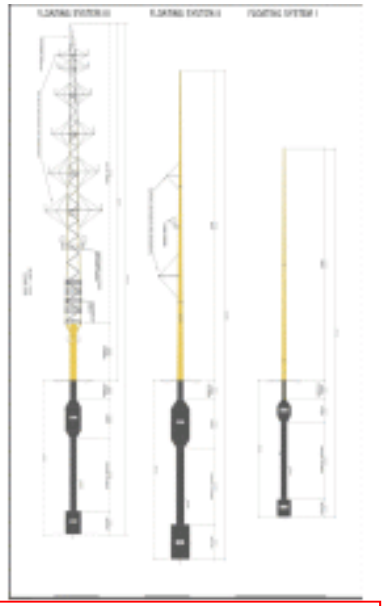
Existing Offshore Met. Mast

Left : Jeju(KIER), Right : Wido(KEPRI)

Fixed type Offshore Met. Mast :

2 ~ 10 mil. US $ [~ 100meter]





IDEMAR METEO

Floating Offshore Met. Mast :

5 ~ 15 mil. US $ [~ 100meter]

Early Offshore Met. Masts Europe

Danish wind turbine testing site

Stand Number	Company	Wind Turbine	MW	Rotor diameter	Hub height	Tip height
1	Empty					
2	Vestas Wind Systems A/S	V164-8.0 MW	8.0	164	140	222
3	Vestas Wind Systems A/S	V126-3.3 MW	3.3	126	116	179
4	Empty					
5	Senvion Energy(중국)					
6	Siemens WindPower GmbH	SWT-6.0-154	6.0	154	120	197
7	Siemens WindPower GmbH	SWT-4.0-130	4.0	130	110	175

Wind turbine height will be over 140 meter afterwards !!!
It will be very expensive to construct a fixed type meteorological mast.

IDERMAR METEO

An alternative… Floating Lidar System

Name	Fraunhofer IWES Wind Lidar Buoy	SEAWATCH Wind LiDAR Buoy	FLiDAR	WindSentinel Floating LiDAR
Type				
Manufacturer	Fraunhofer	SINTEF	FLiDAR	AXYS TECHNOLOGIES

Name	eOLOS	Babcock low-motion spar buoy	SeaRoc
Type			
Manufacturer	Neptune Project by I REC	Babcock	SeaRoc

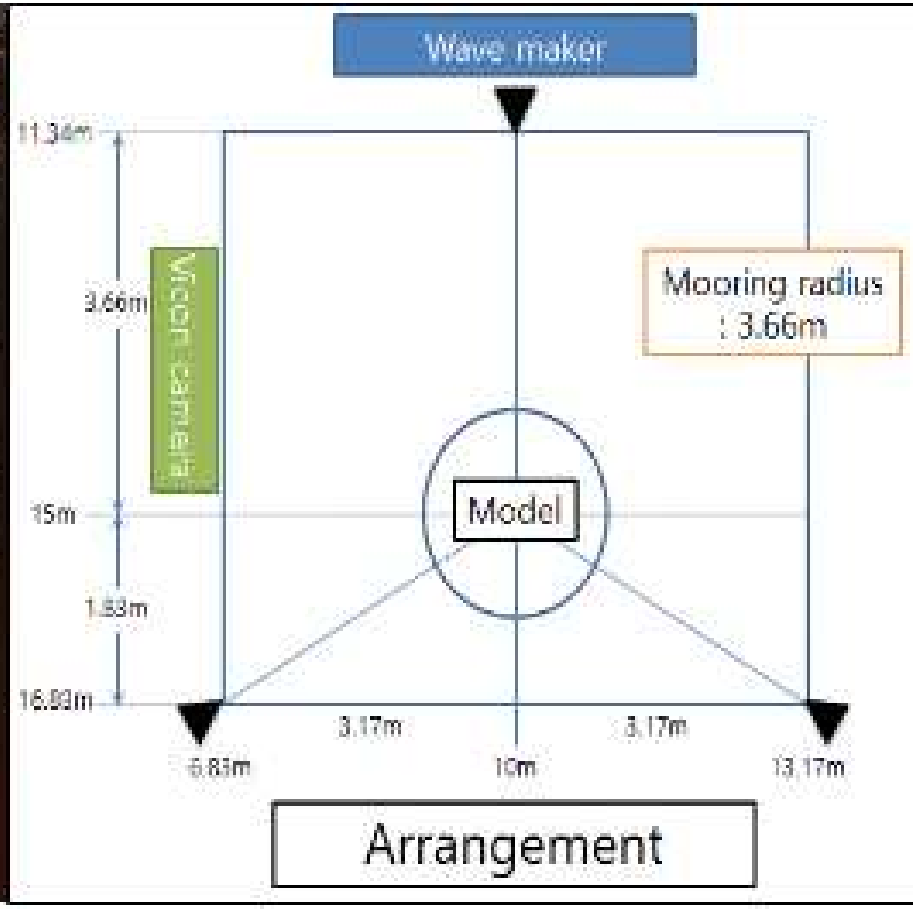
Floating lidar system :

~1 mil. US $ (~200미터)

Standard buoys

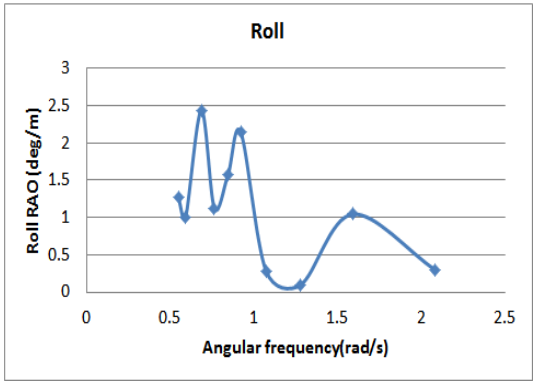
Due to serious motion for Lidar measurement,
more stable surface buoy type is needed

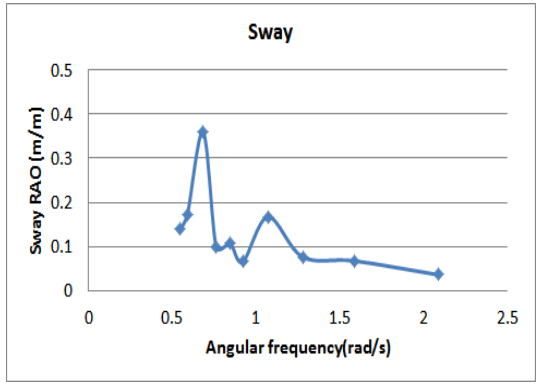
Our initial design : IEA/wind OC3 style

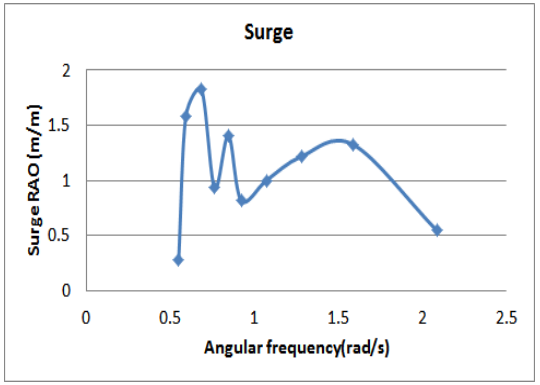


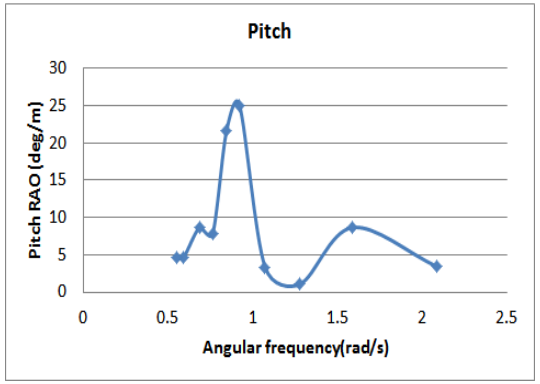
Water tank model testing #1

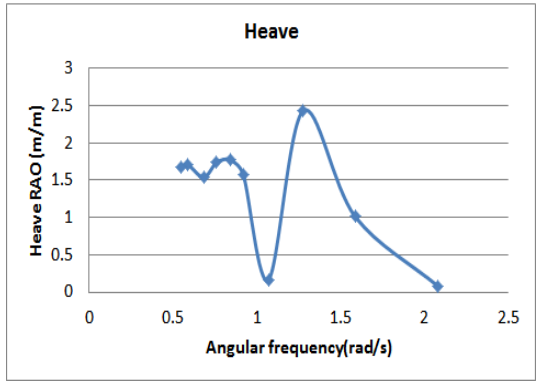
RAO

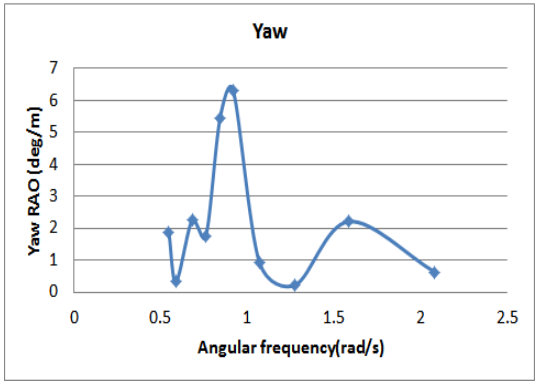




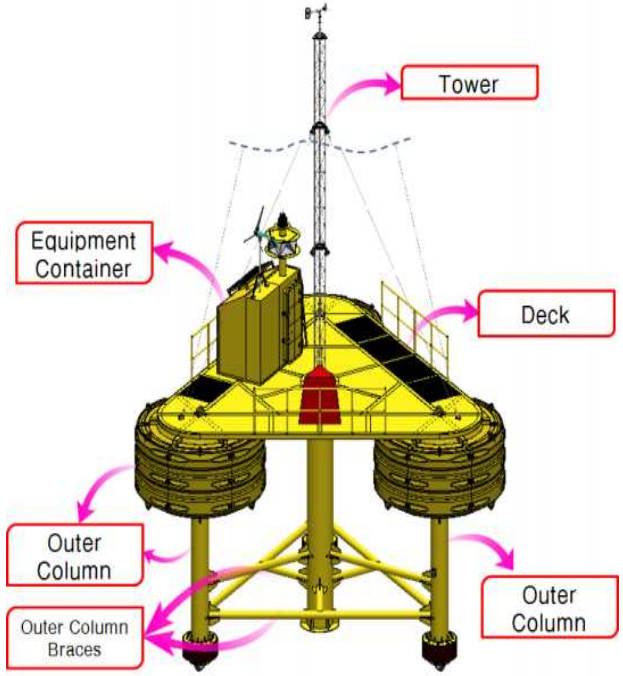


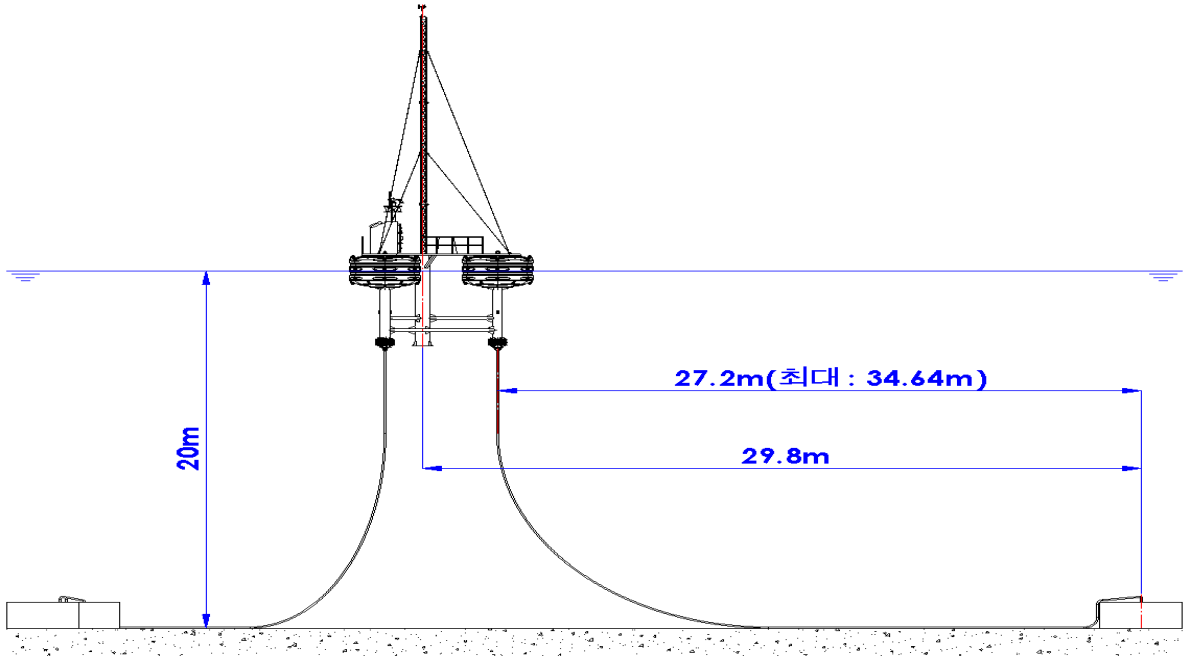




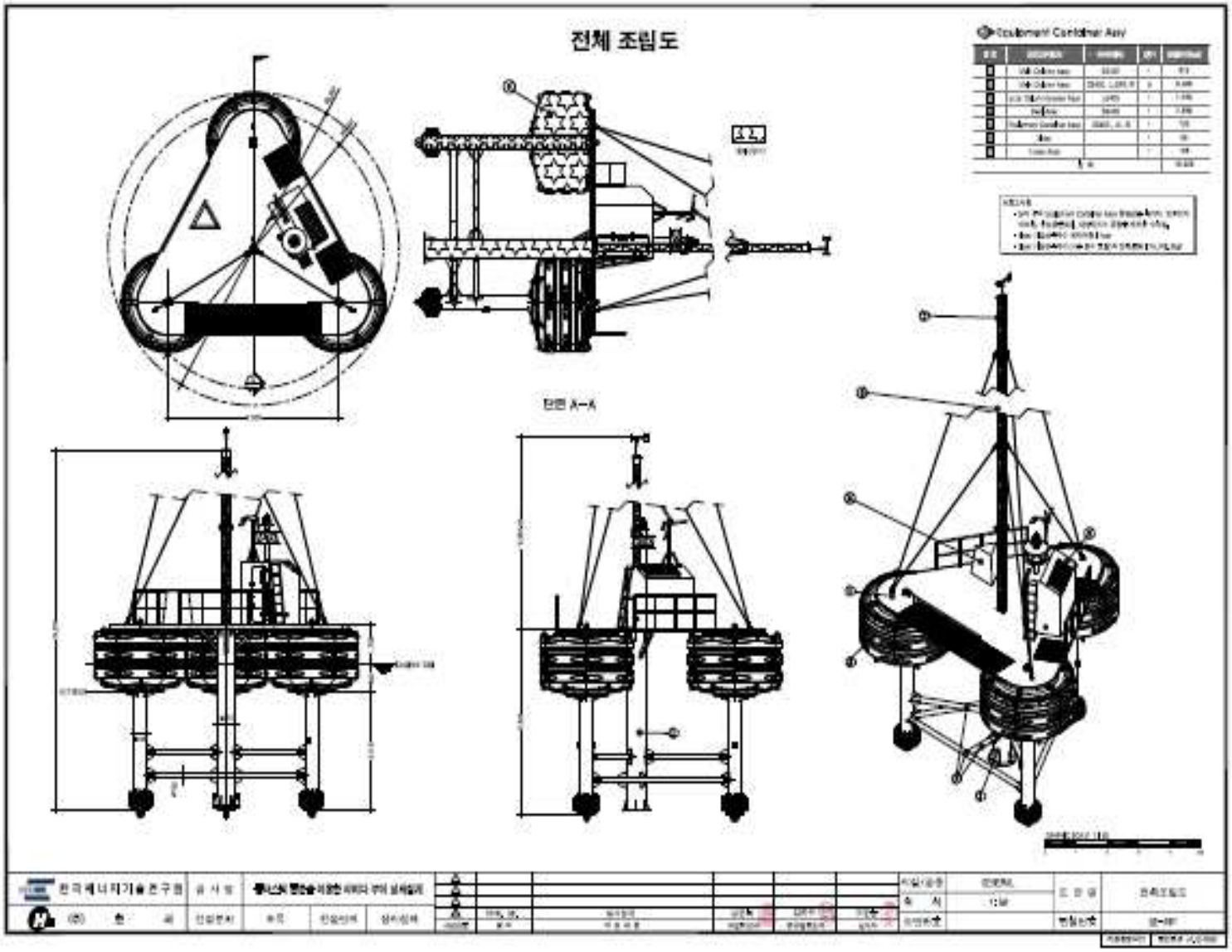


Redesign : Weght⇓ Expense⇓ Res. Freq.⇑





New design : Assembly

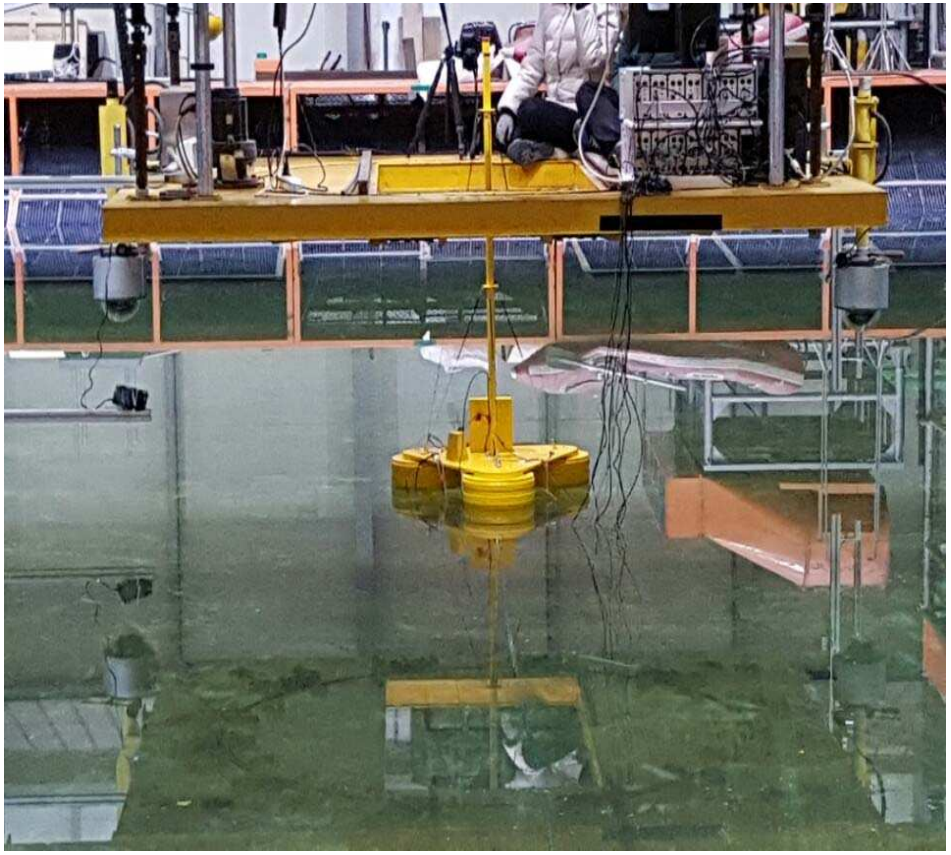


KIER

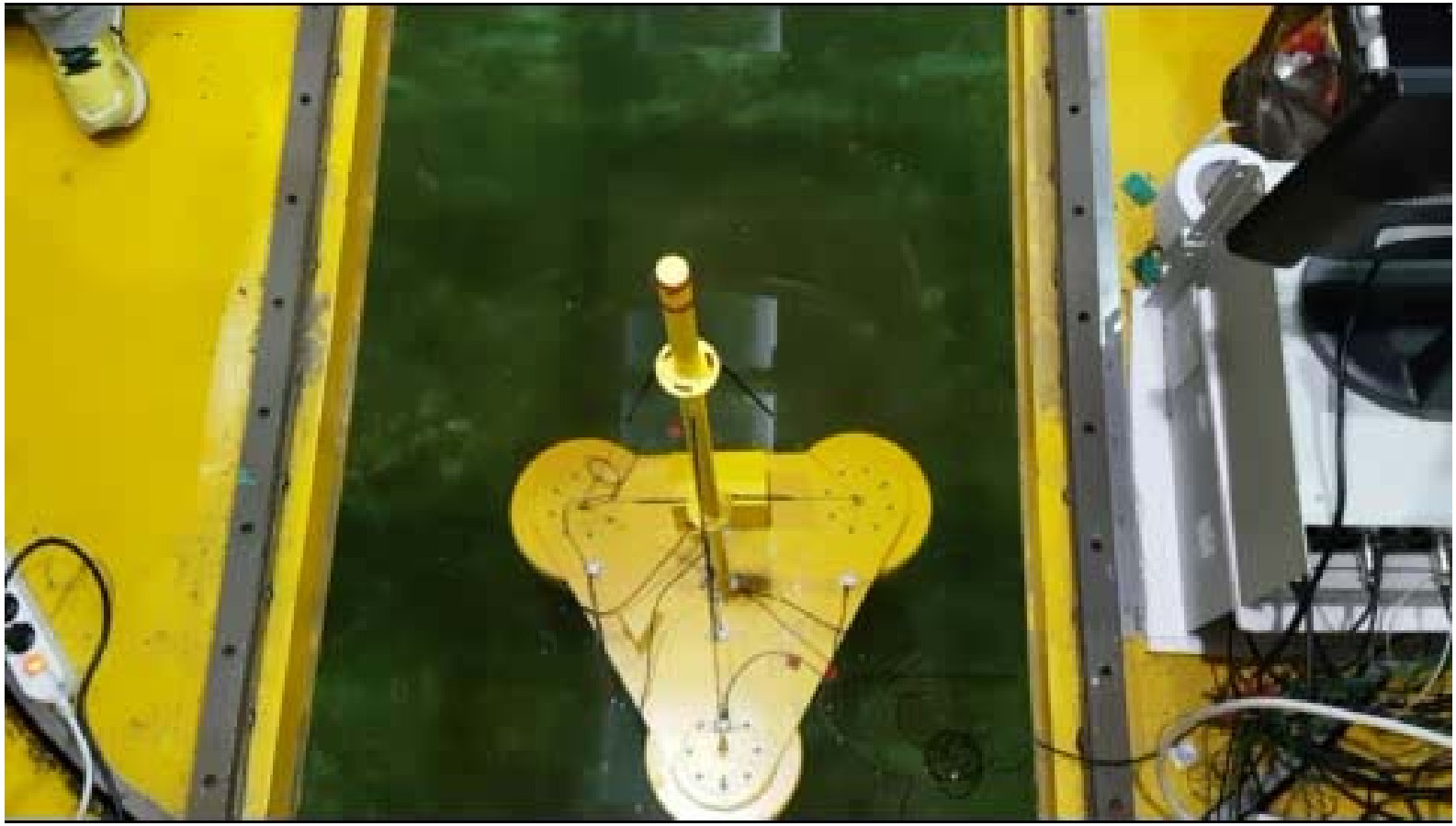
Water tank test 1/10 scale model

(a)

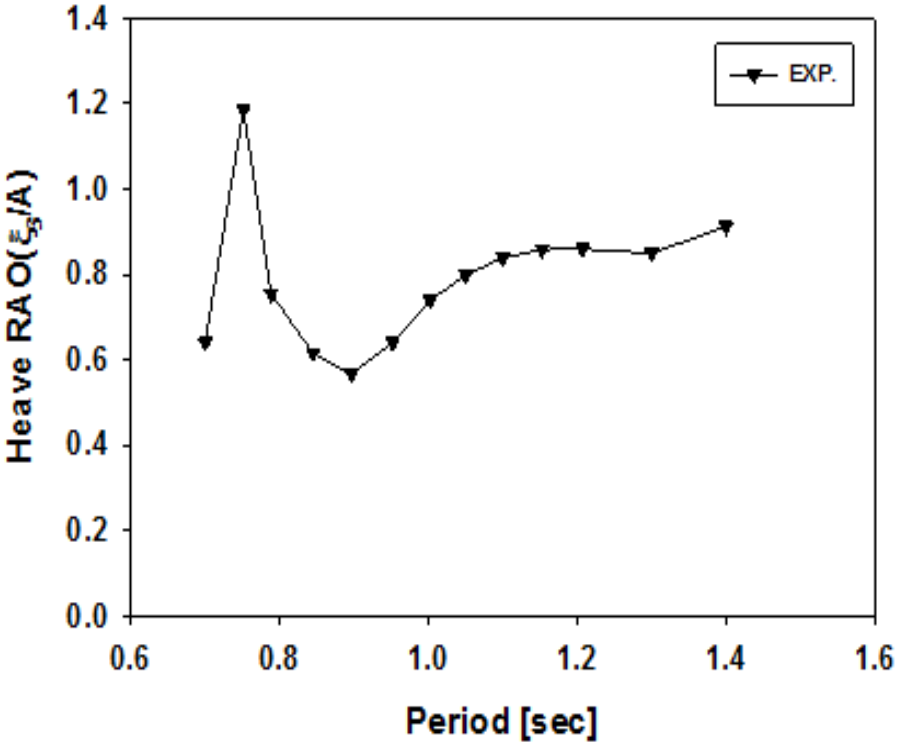
(b)

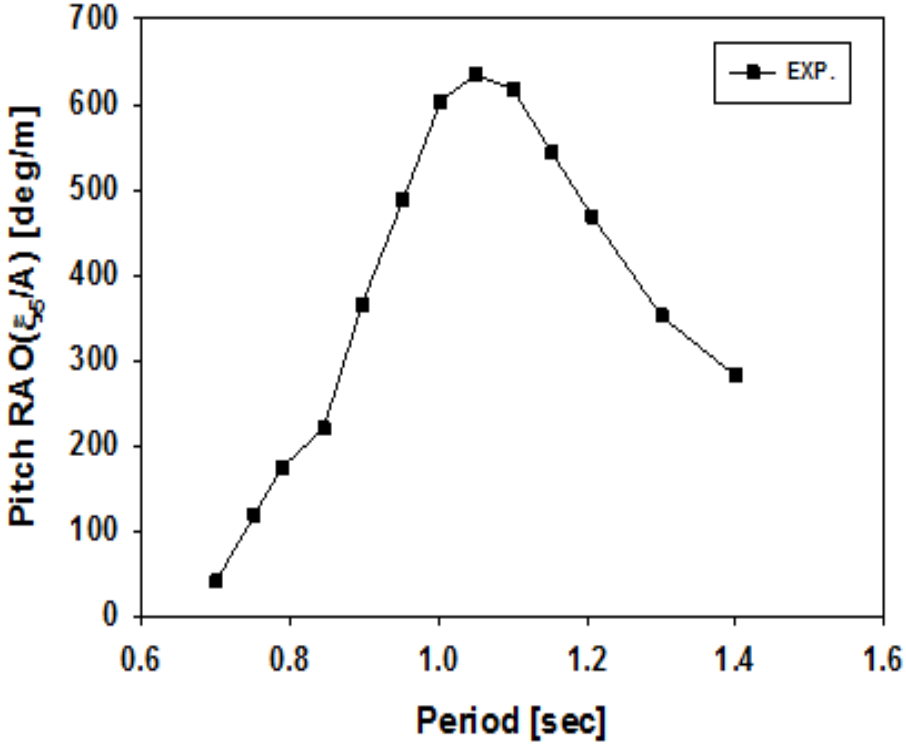


Model Testing Movie 2



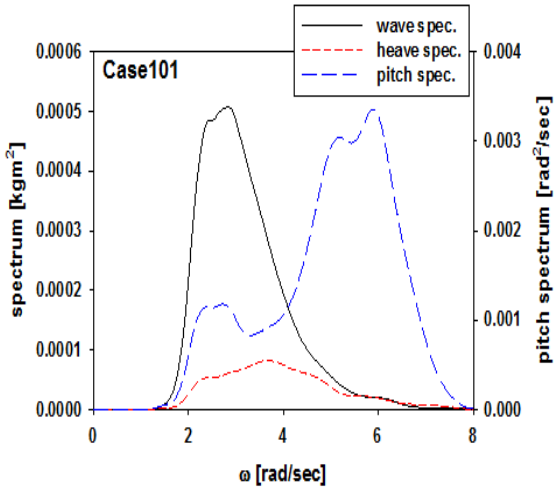
Regular wave

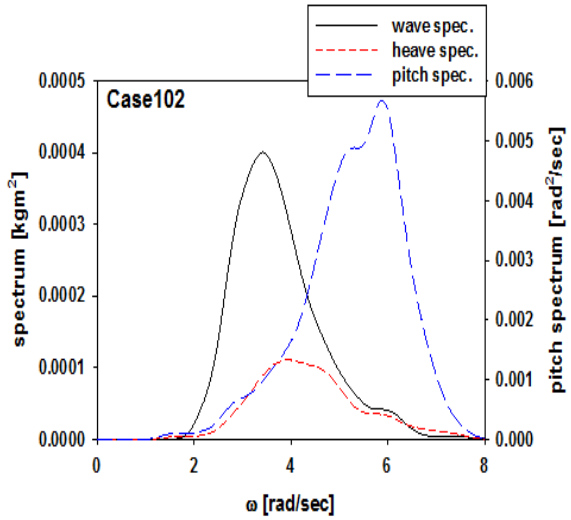


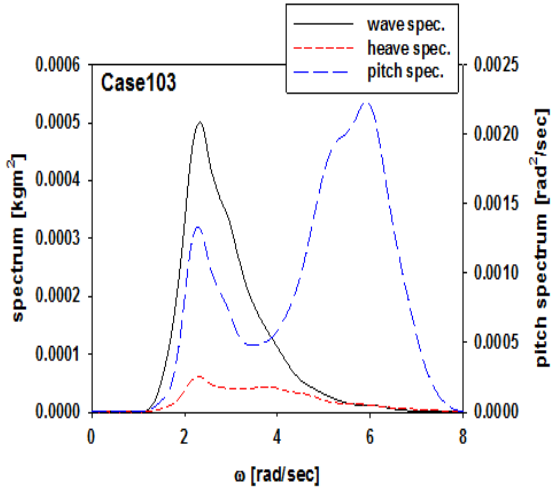


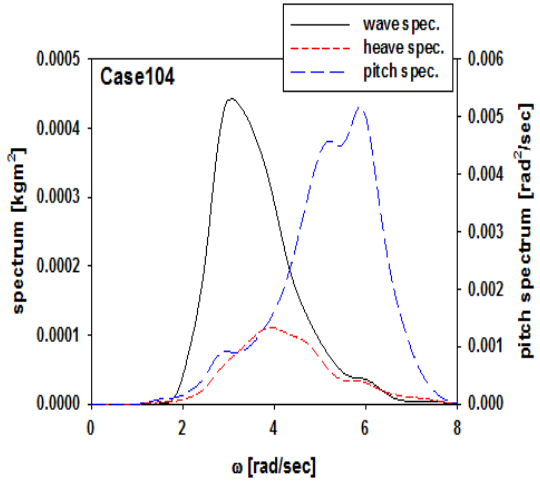
Irregular wave

- Hs=0.118m, Tp =2.412sec Hs=0.106m, Tp =1.939sec
- Hs=0.106m, Tp =2.801sec Hs=0.114m, Tp =2.046sec









Stabilizer Patent

특허증

CERTIFICATE OF PATENT

특 허 제 10-1595357 호

위의 발명은 「특허법」에 따라 특허등록원부에 등록되었음을 증명합니다.

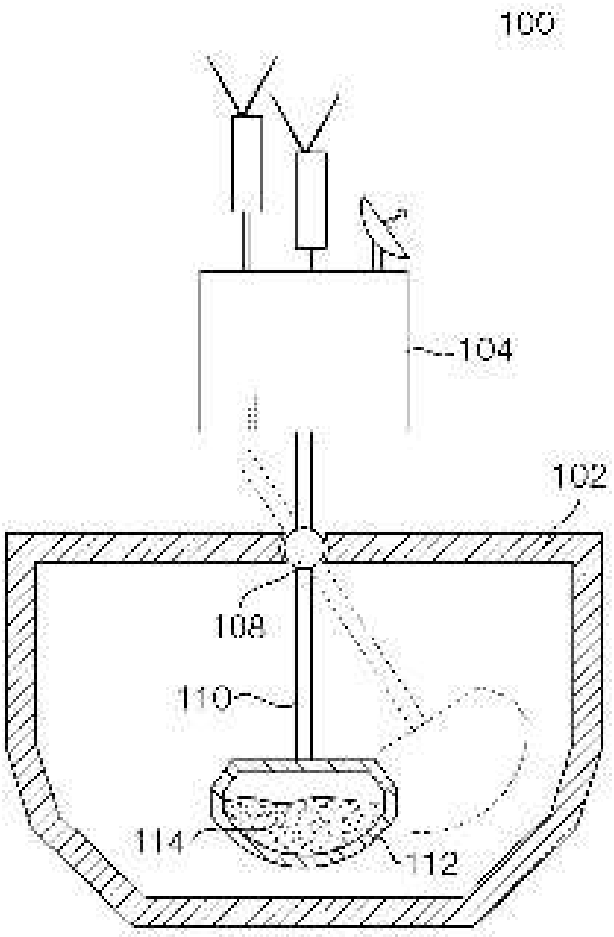
This is to certify that, in accordance with the Patent Act, a patent for the invention has been registered at the Korean Intellectual Property Office.

특허청장

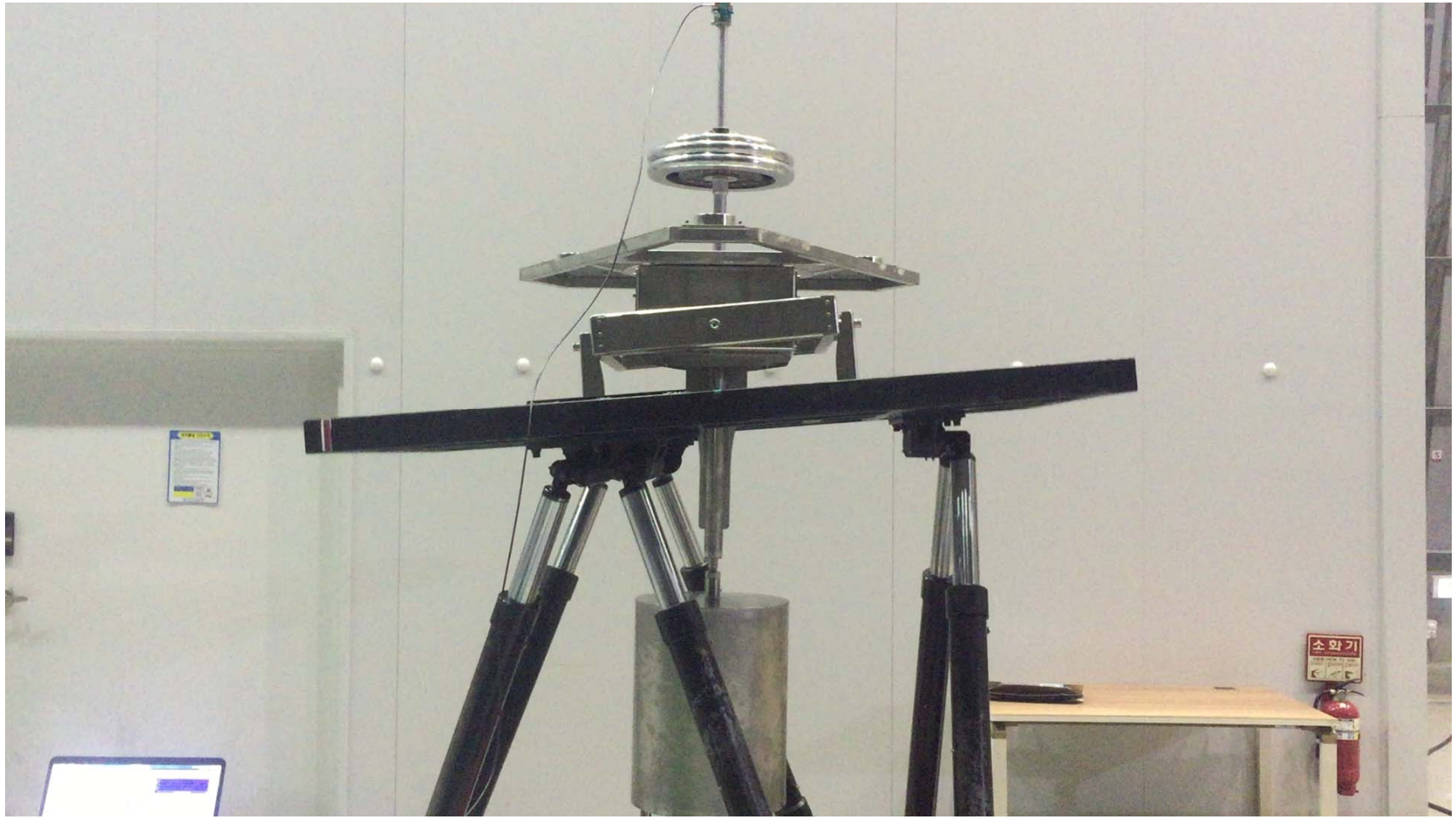
COMMISSIONER

KOREAN INTELLECTUAL PROPERTY OFFICE

최 동 규

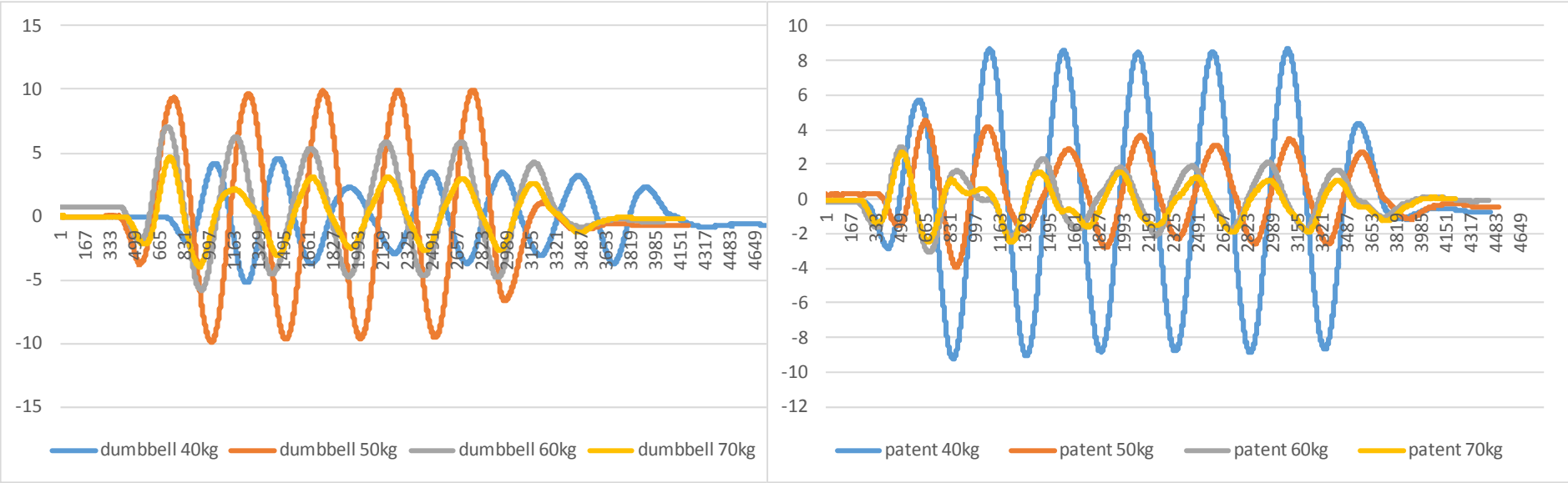


Experiment with a Stewart Platform



Experiment results

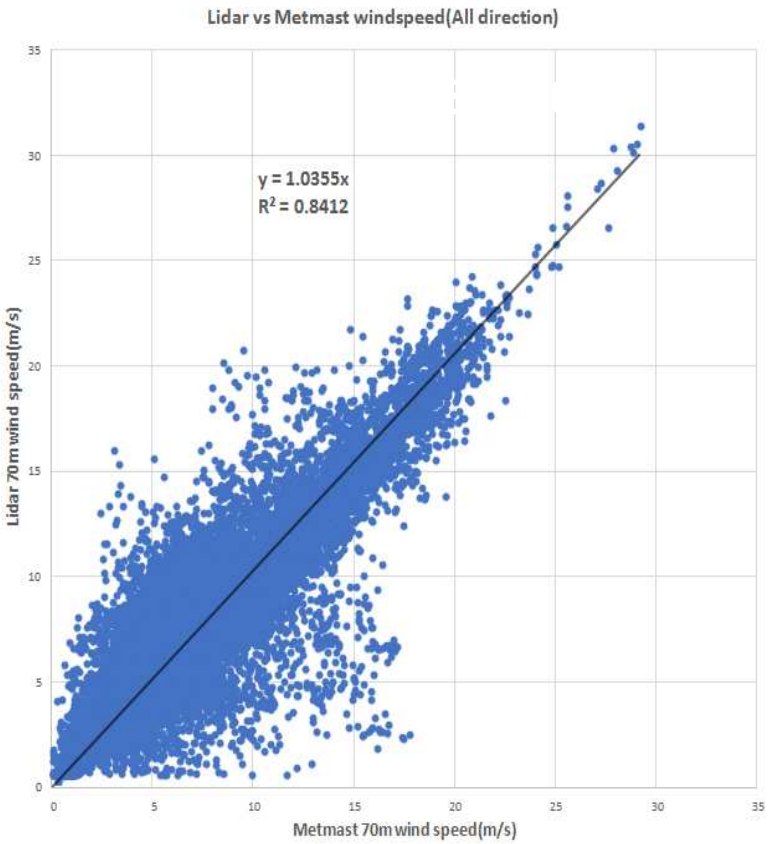
- Stewart Platform ∓10° pitching : For patent, ∓2~3° motion detected

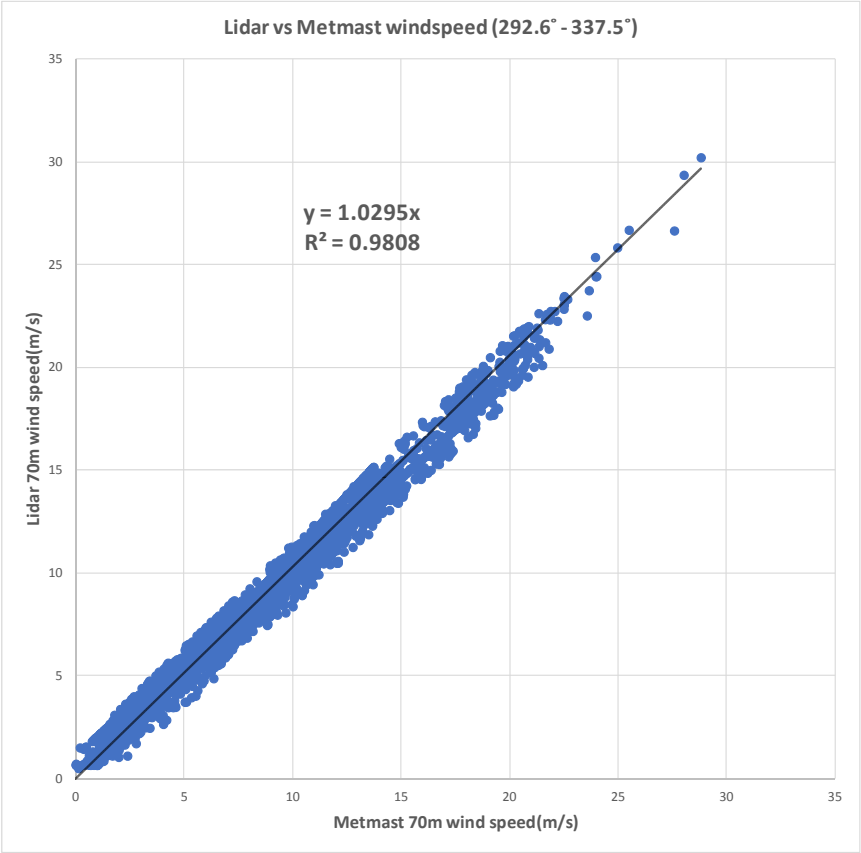


Test field in Jeju

Install lidar for floater near 100m Met. Mast in Jeju

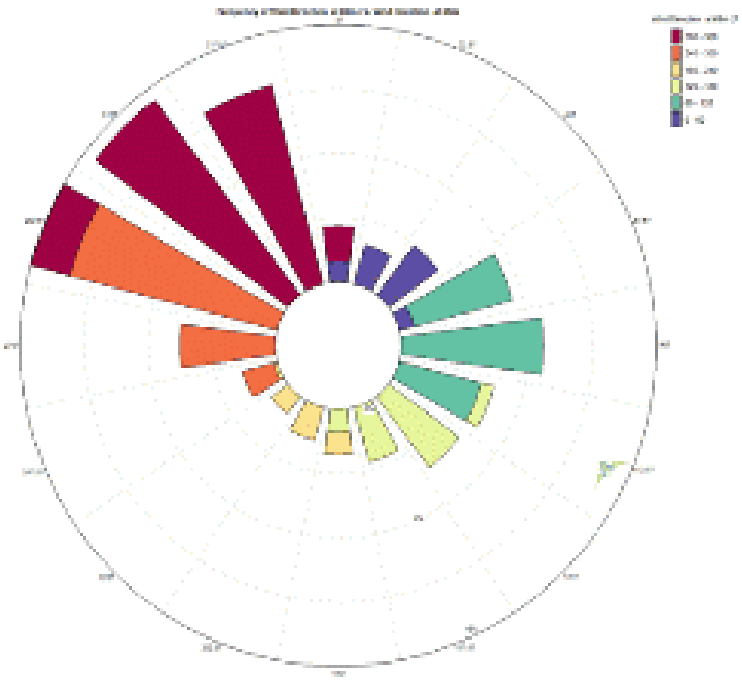
Accuracy check for a lidar on floater

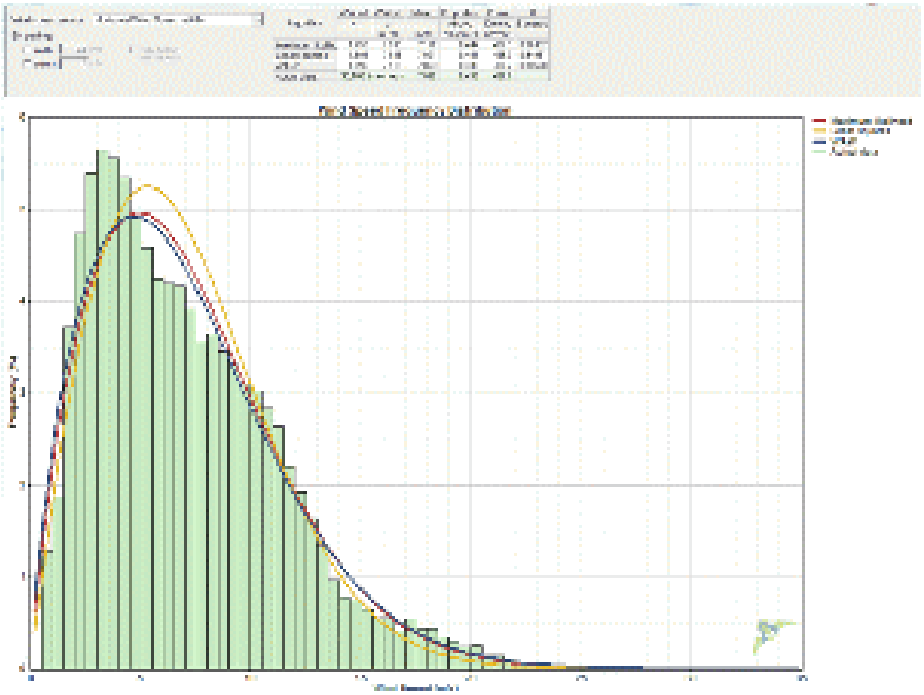




Installed near 100m meteorological mast in Woljeong, Jeju

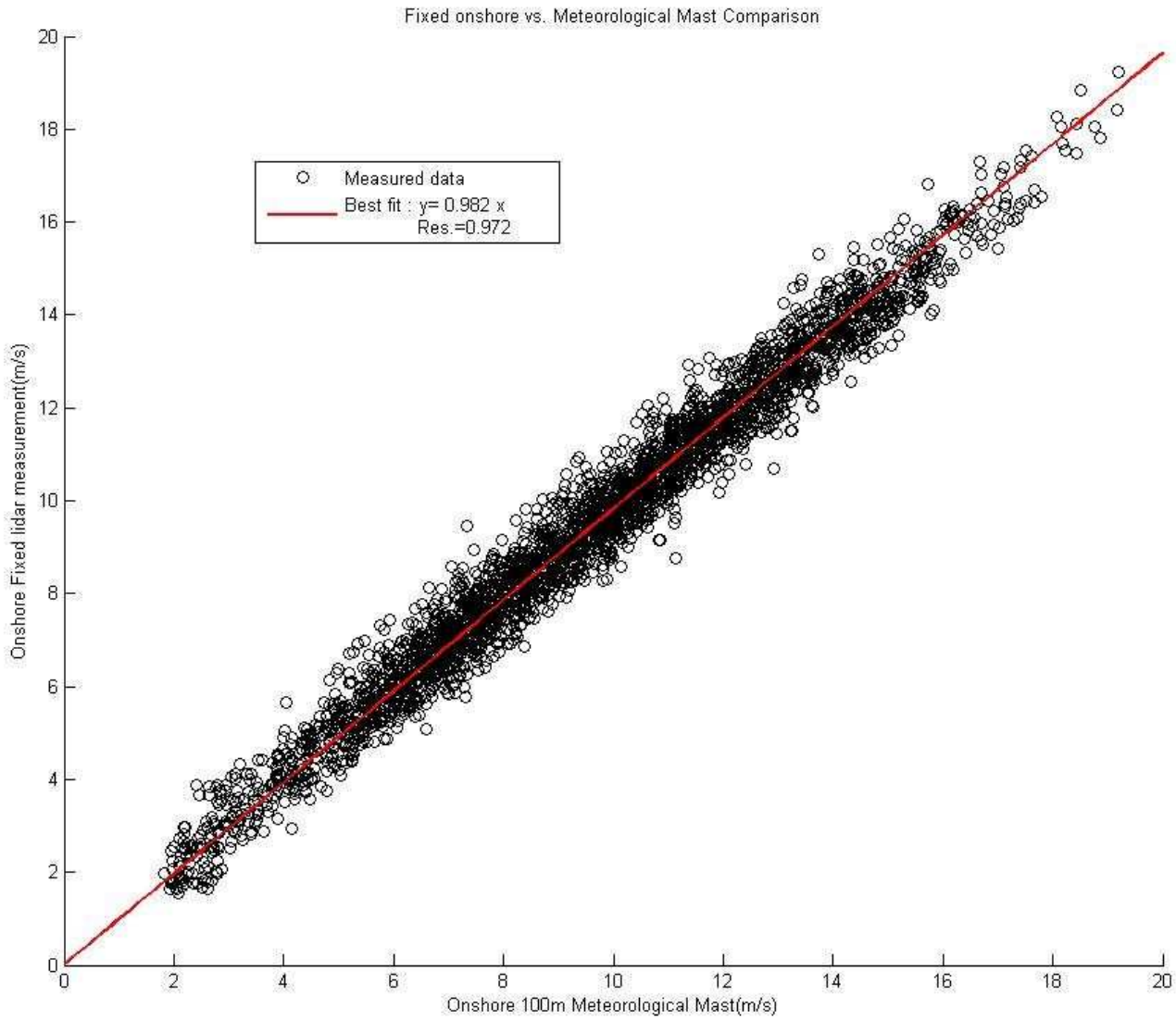
라이다 측정 자료 분석





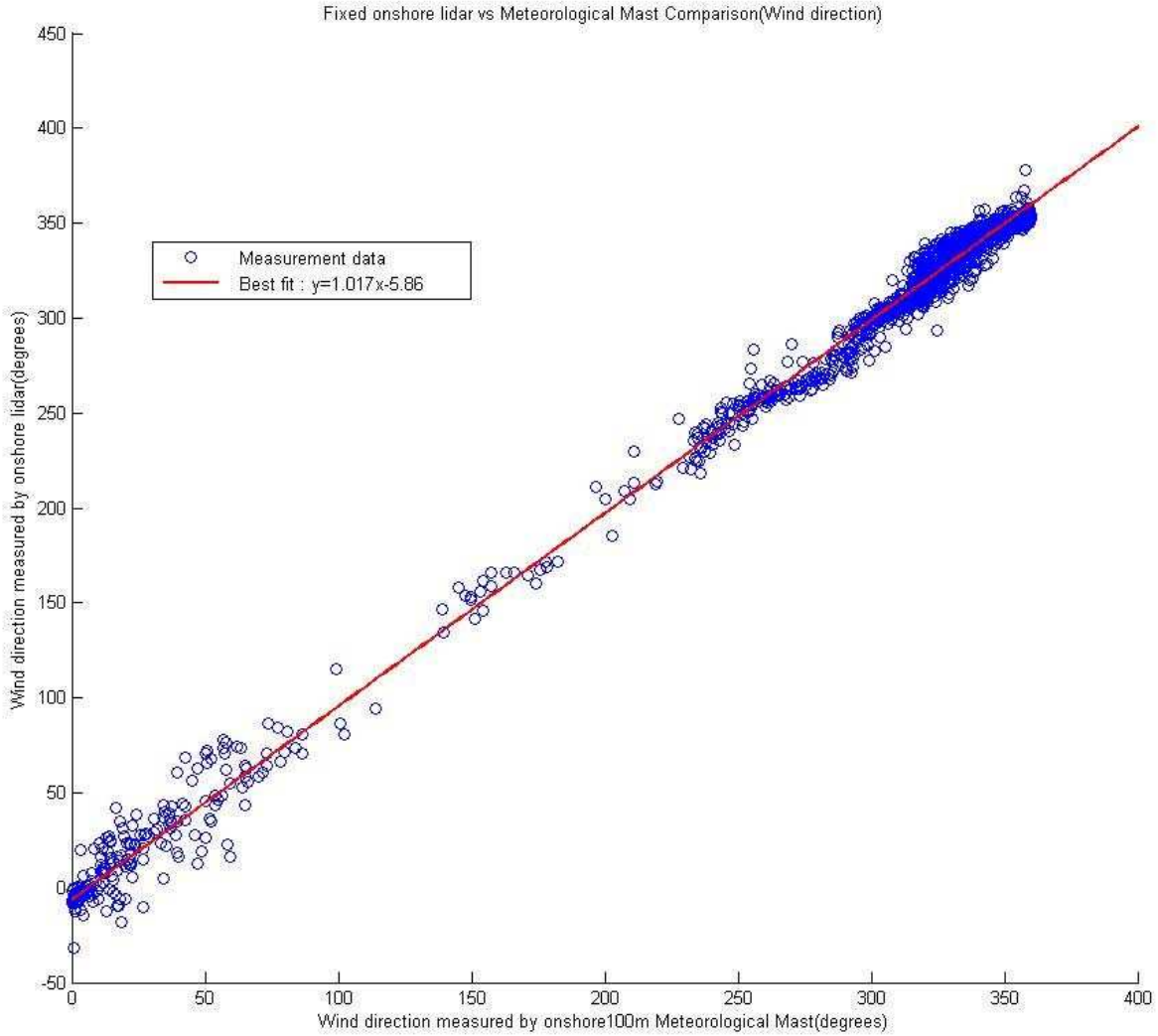
Install leased Lidar near 100m Met. Mast in Jeju

Accuracy check for a lidar onshore fixed : wind speed



KIER

Accuracy check for a lidar onshore fixed : wind direction



Transport and Installation of floating lidar system

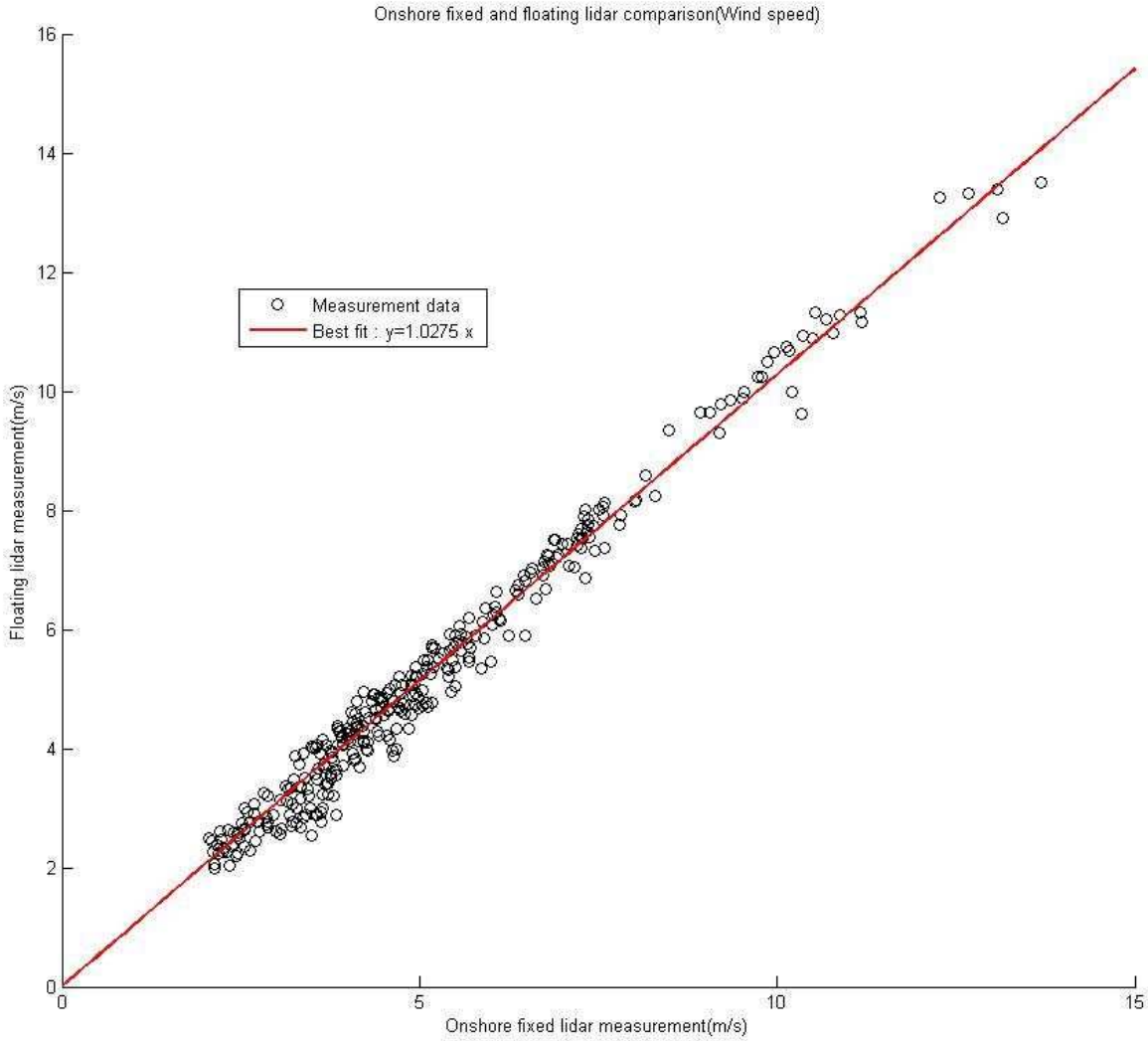
… a good calm day … ^^

Operation of our floating lidar, Haedong-13

Onshore lidar vs. Floating Lidar

After finishing installation… in a rainy day… ㅠㅠ

Onshore fixed vs. floating lidar comparison



Conclusion

- Comparison between FLS measurement data versus fixed onshore lidar data satisfies the acceptance criteria suggested by IEA Wind annex 32, partly, i.e.
  - Wind speed slope <3%
  - Wind direction slope <5%
- Installation processes for FLS is much faster and easier than offshore met. mast since permission process is much simpler.
  - Mobile to any place, little damage to seabed
  - Consensus with inhabitance is not mandatory
- Applicable to shallow marine area, however, for deep see, the present FLS system should be modified to withstand high wave and current.

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Thank you!