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Offshore Wind Farm Construction within Precautionary Action Zone

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Summary

Most critical obstacles for offshore wind farm construction in Korea are environment impact, public acceptance and grid connection. Although the government sets up Renewables 3020 which intend to produce 20% of national total energy production by renewables up to 2030, it's not easy to achieve the goal without any breakthrough overcoming those obstacles. Considering those given circumstances in Korea, a nuclear power plant shut down or to be shut down permanently can be a possible way out. In this regard, an offshore wind farm built in precautionary action zone of a nuclear power plant has been studied in aspect of technological and economic feasibility.

1. Introduction

Kori nuclear power plant has 4 nuclear reactors with total installed capacity of 2.8GW. Unit #1 reactor commissioned in 1978 and permanently shut down in 2017. As a consequence of the shutdown, the substation of Kori NPP has reserve capacity of 585MW, which can be utilized to accommodate offshore wind farm. For safety purpose, every nuclear power plant has precautionary action zone (PAZ), which is 5km in radius for Kori NPP as indicated in Fig. 1. If offshore wind farm can be built in PAZ, then the government initiative of Renewables 3020 could gain more support from stakeholders and the public.

One of the most important advantages is that grid connection cost can be sharply reduced by using spare capacity of Kori NPP substation.

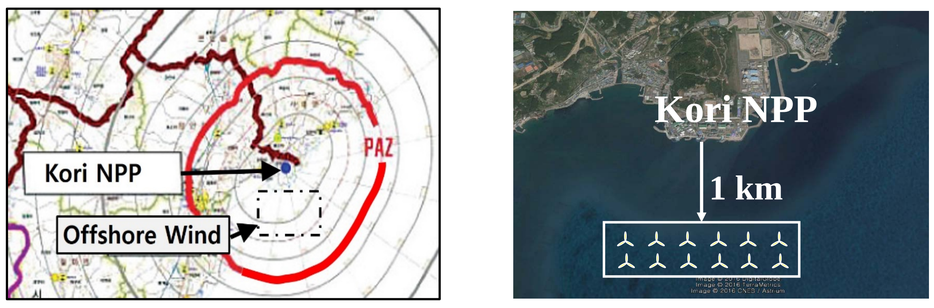


Fig. 1 Offshore Wind Farm in Precautionary Action Zone of Nuclear Power Plant

2. Wind Resource

Wind resource at the site in front of Kori nuclear power plant is under measurements using a lidar from March 2018 and a draft results will be available in May 2019.

Using satellite data, mean wind distributions at the height of 10m(WSPD0), 40m(WSPD1), 80m(WSPD2), 120m(WSPD3), 320m(WSPD4), 470m(WSPD5), and 670m(WSPD6) are analyzed and the results show that the mean wind speed is 6.795m/s at 120m height.

Table. 1 Variables of the Satellite Data

Variable	Value
Latitude	N 35.311268
Longitude	E 129.304290
Elevation	0 m
Start date	2012-01-01 00:00
End date	2013-01-01 00:00
Duration	12 months
Length of time step	60 minutes
Calm threshold	0 m/s
Mean temperature	284 K
Mean pressure	937.4 hPa
Mean air density	1.149 kg/m3
Power density at 50m	243 W/m?
Wind power class	2 (Marginal)
Power law exponent	0.115
Surface roughness	0.0112 m
Roughness class	0.80

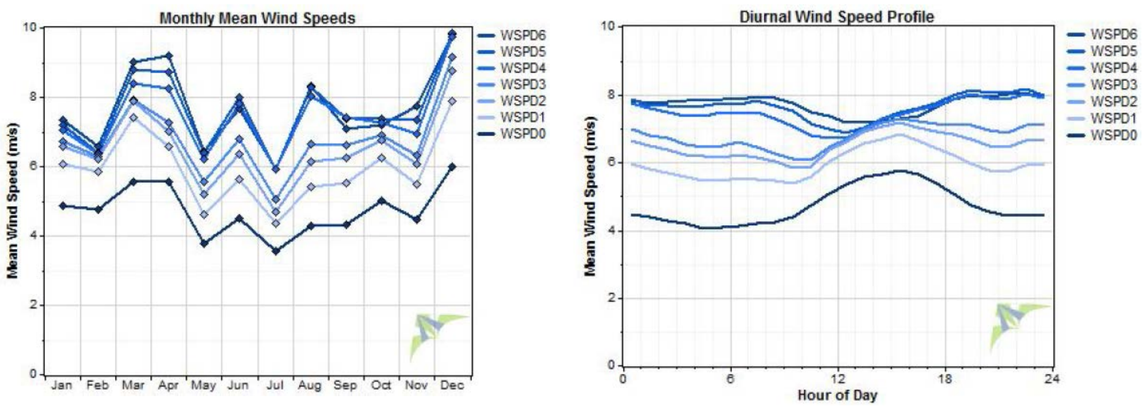
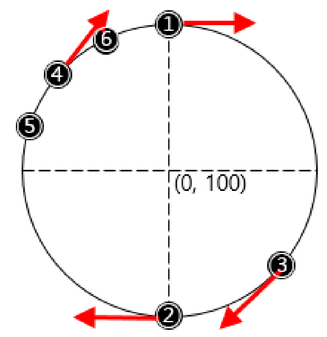


Fig. 2 Monthly Mean Wind Speeds and Diurnal Wind Speed Profiles

3. Structural Safety

One of the most important processes is structural safety analysis of nuclear power plant when offshore wind farm construction is considered in precautionary action zone because nuclear reactors are enclosed by concrete structures to protect from external impacts caused by wind turbine structural failure. If a blade failure occurs and fragments of broken blades hit concrete enclosures directly, then it shall be regarded as a major threat to nuclear power plant safety. Under the assumption of that single blade weighted of 17,740kg directly hit the concrete structure, as the worst case scenario, damages of the structure has been estimated using elastic model. There are 6 different cases in terms of blade terminal impact velocity and angle for structural safety simulation as illustrated in Fig. 3. The fastest impact velocity is when a blade is released to fly away at case 4 location and the results show that blade fails to reach at the nuclear power plant.

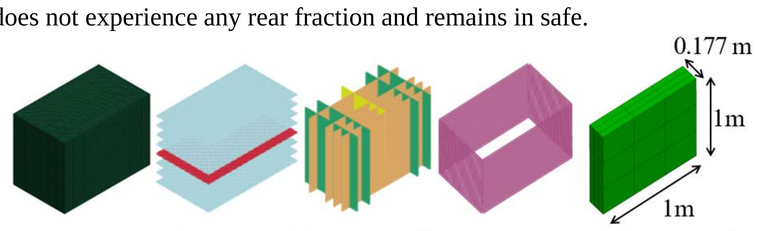


Impact velocities & angles

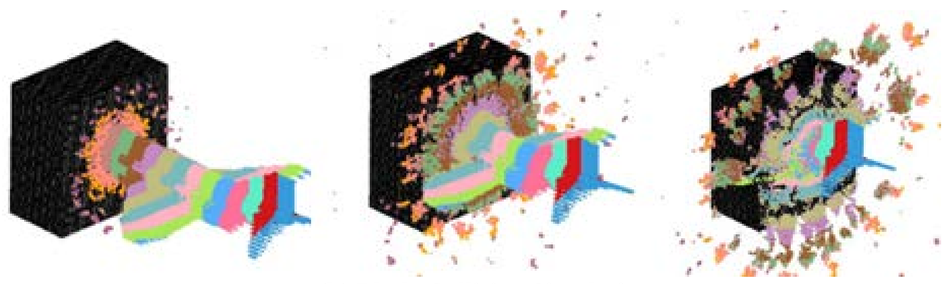
Case 1 : 100.2m/s 27.9°
Case 2 : 90.6m/s 15.3°
Case 3 : 94.7m/s 30.9°
Case 4 : 101.5m/s 32.4°
Case 5 : 100.6m/s 32.8°
Case 6 : 100.9m/s 30.9°

Fig. 3 Case Studies for Blade Fragments Terminal Impact Velocities and Angles

Even when a blade collides with concrete shielding structures of nuclear power plat, the simulation results show that the structure does not experience any rear fraction and remains in safe.



(a) Concrete Shielding Structure Modelling (Total mass 300kg, Density 1,700kg/m^3)



(b) Blade Collision Simulation

Fig. 4 Blade Collision with Concrete Shielding Structure Simulation

4. Kori NPP's Switch Yard Connection with Offshore Wind

Kori NPP has a rated capacity 2,500MW in total with 3 reactors still in operation as indicated in Table 2 and the offshore wind farm in consideration is to be connected to Kori NPP's switch yard to save grid connection cost.

Table. 2 Kori NPP's Power Generation Capacity

	Rated Capacity [MW]	Max. Output [MW]	Mbase [MVA]	
Kori NPP #1G	-	-	-	Shut Down
Kori NPP #2G	650	663	840	In Operation
Kori NPP #3G	950	1,033	1,222	In Operation
Kori NPP #4G	950	1,032	1,222	In Operation

Kori NPP has a rated capacity 2,500MW in total with 3 reactors still in operation as indicated in Table 2 and the offshore wind farm in consideration is to be connected to Kori NPP's switch yard to save grid connection cost.

Power output from offshore wind is strongly effected by wind speed change which might drive Kori NPP switchyard into unstable state because Kori NPP #2 generator is to be tied with the offshore wind farm of 60MW.

In this regard, breakdown capacity, load flow and load factor of transmission lines have been analyzed. P-V analysis shows that inadvertent interchanged power margin is 918.75MW in normal operation condition and the voltage is 0.999pu at the former Kori NPP #1G.

Based upon V-Q analysis, bus voltage of the former Kori NPP #1G has stability limit at 0.84pu and improves reactive supply margin up to about 2,540MVar.

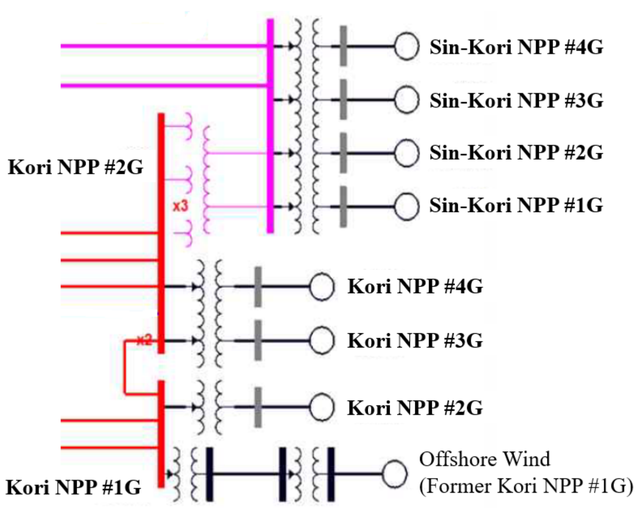


Fig. 5 Kori NPP Switchyard

5. Conclusions

Offshore wind farm constructed in precautionary action zone shall not affect safety of nuclear power plants. In the present study, two (2) important NPP's safety related issues are investigated and the results are;

- Wind turbine failures including blade does not impact on NPP's structural safety.
- Intermittency of power generation from offshore wind farm does not disturb Kori NPP switchyard.
- Kori NPP is able to accommodate up to 600MW of offshore wind farm without any safety sacrificing of operation and maintenance.

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