Load Estimation and O&M costs of Multi Rotor Array Turbine for the South Baltic Sea

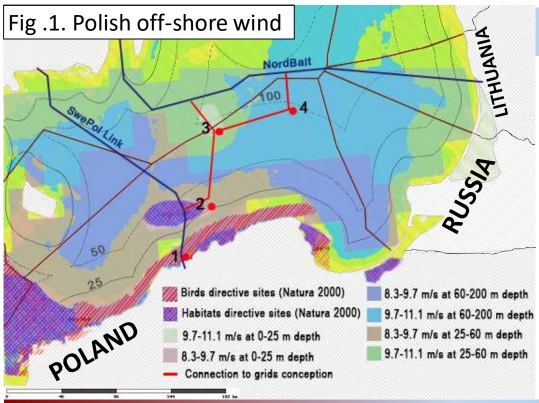
NTNU – Trondheim
Norwegian University of Science and Technology

Maciej Karczewski[1*], Piotr Domagalski[1], Michal Lipian[1], Lars Roar Saetran[2]

[1] Institute of Turbomachinery, Lodz University of Technology, Lodz, Poland, *Email: maciej.karczewski@p.lodz.pl

[2] Department of Energy and Process Engineering, Norwegian University of Science and Engineering, 7491 Trondheim, Norway.

Fig .1. Polish off-shore wind

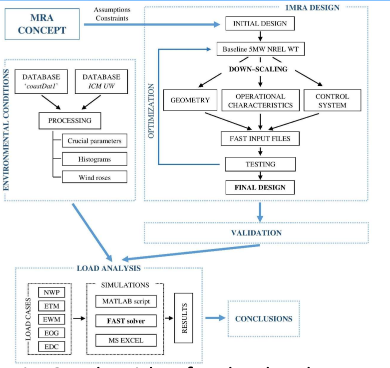


Introduction

- Poland experiences energy shortage at northern parts of the country;
- Polish RES bill significantly limited operations for on-shore wind;
- Gov't plans to support 2-3 shallow off-shore farm locations, but no sight for overall cost reduction and instigation of local heavy industry;
- **AIM1: explore deep off-shore wind locations such as our idea of location 4 to show costs can be reduced.**
- **AIM2: propose floating off-shore wind turbine design in the form of Multi Rotor Array (MRA) to mitigate cost and technology problems. AIM3: revitalise Polish shipyard industry around our own MRA concept.**

Methodology

- Evaluated benchmark Vestas V100 2 MW turbine for costs at all 4 loco by using NREL design cost and scaling model[1];
- Designed a layout of 7 rotor MRA and scaled the baseline NREL 5 MW single rotor turbine[2] down to a 0.714 MW;
- Analysed hourly metocean data for the 50-year period;
- Preapred a FAST add-on tool in Matlab and verified structural integrity of MRA rotors using aero-servo-elastic solver FAST ver 8.0 against approved load cases[3];
- Measured performance of the proposed MRA and compared it to baseline NREL 5 MW turbine.



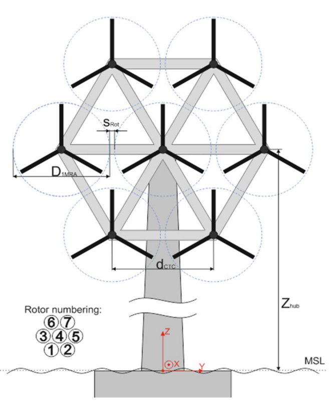
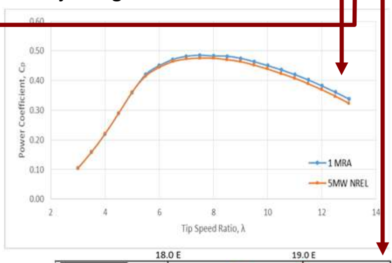


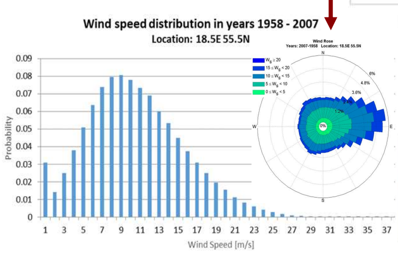
Fig. 2. Algorithm for the development and evalution of MRA

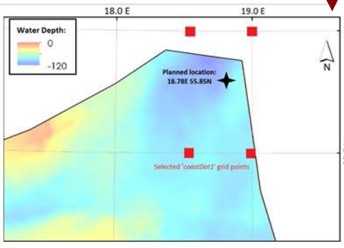
Numerical model

- RNA of the baseline turbine was Froude scaled to derive mass of our 1MRA rotor[1];
- Steady-state validation of the scaled rotor model made;
- Average/extreme sea state from coastDat1 DB for location 4:
  - Mean wind speed V_{ave50}=10.1m/s, extreme V_{max50}=36.7m/s,
  - Mean signific.wave height H_{ave45}=1.2m, wave period T_{ave45}=5.19s, extreme H_{max45}=9.9m, T_{Hmax45}=12.3s.
- Power law wind shear exponent=0.14 adjusting induction to MRA

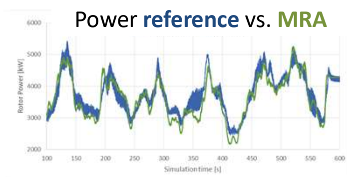
INPUT PARAMETER	FACTOR
Blade and hub radius	κ_L
Blade, hub, nacelle mass	κ_L^3
Hub, nacelle, generator moment of inertia	κ_L^5
Nacelle CM location in (X), (Y) and (Z)	κ_L
Mass ratio (mass per unit length)	κ_L^2
Blade flapwise/edgewise'stiffness ratios	κ_L^3

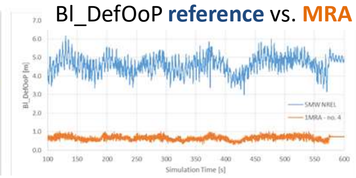




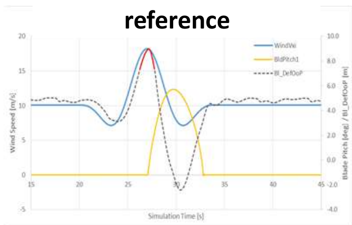


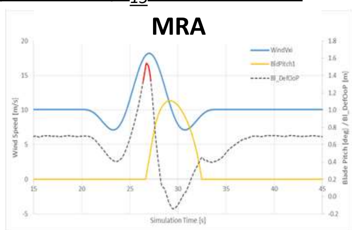
Initial results





Normal Turbulence Model (NTM load) I_{15}=0.16 and a=3





Extreme Operating Gust (EOG load) V_{hub}=10.1 m/s

Model	Bl_DefOoP				Bl_RootMx [kNm]			Bl_RootMy [kNm]		
	1MRA		NREL		1MRA	NREL	%	1MRA	NREL	%
	[m]	NC%	[m]	NC%						
$NWP_{8.0}$	0.45	*23.4*	3.36	*31.9*	37.95	4277	*0.89*	290.8	6065	*4.79*
$NWP_{11.4}$	0.81	*42.2*	5.31	*50.5*	75.15	4956	*1.52*	530.5	9772	*5.43*
$NWP_{18.0}$	0.29	*15.1*	1.97	*18.7*	71.49	4929	*1.45*	248.7	5195	*4.79*
NTM	1.04	*54.2*	6.17	*58.7*	182.3	5376	*3.39*	702.7	11370	*6.18*
EWM	1.04	*54.2*	6.10	*58.0*	512.1	11190	*4.58*	503.5	10590	*4.75*
EOG	**1.54**	*80.2*	**8.97**	*85.3*	153.6	5056	*3.04*	1028	16190	*6.35*

References

[1] Fingersh L., Hand M., Laxson A., *Wind Turbine Design Cost and Scaling Model*, Technical Report NREL/TP-500-40566, 12/2006.

[2] Jonkman J., Butterfield S., Musial W., Scott G., *Definition of a 5-MW Reference Wind Turbine for Offshore System Development*, Technical Report. NREL/TP-500-38060, 02/2009.

[3] Germanischer Lloyd WindEnergie (GL), *Guidelines for the Certification of Offshore Wind Turbines*, 2005.

Summary & conclusions

- Deep off-shore wind in Polish territorial waters: abundant and economically sound
- Around 7% overall COE reduction of location 4 as compared to loco 1
- 62% RNA mass reduction when moving from the 5 MW to MRA
- EOG load led to breaching the safety margin by 10.2% and 15.3% of allowable blade tip clearance for 1MRA and NREL designs respectively
- Proposed MRA rotor withstands other loads by substantial margins