Reliable design and maintenance optimization of offshore wind turbine jacket considering fatigue and corrosion.

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Renewable energy development in the world is crucial, in order to tackle the climate change and increasing energy demand. In fact, the reduction of emission of the greenhouse gases requires an increase of the renewable energies. The European Union aims to reach the production of electricity from renewable energies to 27% in 2030. Wind energy is considered as the most promising and economically viable source of renewable energy. The Global Wind Energy Council (GWEC) predicts that the global annual growth rate of wind power will exceed 12% between 2013 and 2018. The European Wind Energy Association (EWEA) predicts with a central scenario that the installed capacity in Europe of wind power in 2020 can reach 192 GW, where it will be increased by 64% compared to 2013.

The context of this thesis is the development of offshore wind turbines. Wind power is crucial importance in Normandy, which represents the second field in France. INSA and LMN have industrial collaborations on these issues with major industrial players in the sector.

The reduction of the wind energy cost depends on the costs of their several components (turbine, steel tower and foundation, transport and installation, offshore substation, Electrical infrastructure, etc.). However, the most significant cost elements of offshore wind farms are the turbine, substructure and foundation. The substructure and foundation cost approaching 15% to 20% for fixed-bottom offshore and go up to 36% for the floating offshore wind turbine. In fact, the substructure and foundation cost depends on the installation, on the distance of the wind turbine to the land side and the type of the foundation (monopile, jacket, floating, etc.) [1,2]. Moreover, the cost due to corrective maintenance of the wind turbine components implies high cost for repair and replacement, leading to large investment losses and increase the wind energy cost.

Thus, increasing the economic viability of offshore wind turbine farms is related to the cost reduction due to their components and maintain the mechanical performances to the operational level. This Ph.D thesis aims to search the best reliable and economical design of the wind turbine jacket with considering the fatigue and corrosion degradations due to aggressive and uncertain environment. The support structure of offshore wind turbines involves effective reduction of the installation cost. The jacket structures are widely used in oil and gas sector, where is also used in deep water offshore wind turbines. A jacket is a truss structure composed of steel pipes, welded together in several joints. The dynamic response of the jacket structure due to the wind and wave loads leads to fatigue damage and crack propagation at the location of the welded joints. Moreover, Corrosion degradation is often observed in the offshore structures due the effect of harsh environment. The corrosion degradation induces loss of material, that last causing loss of performances and failure.

This PhD work aims to develop a general framework to search the best reliable design of the jacket structure regarding cost and safety assurance. Structural optimization of the jacket structures is usually carried out by minimizing the structural cost under several mechanical constraints (stress, deformation, buckling, fatigue, vibrations, etc.). The reliability-based design optimization (RBDO) is already used to find the best design of these structures that ensure more reliability. This approach uses stochastic information about the problem and take into account uncertainties arising from the stochastic nature of

the wind actions, fluctuations caused by environment parameters, the material properties and welded joints. A very common framework for modeling uncertain parameters is within probabilistic approaches leading to a probabilistic characterization of the structural response, However, other alternatives include non-probabilistic approaches, or interval methods can be investigated.

In the proposed PhD work, the RBDO of the jacket will be achieved by considering the uncertainty in the structural degradations, by considering fatigue damage and corrosion. In other words, when the mechanical performances can be significantly reduced due to different degradations, the design optimization should take into account the time-dependency of the probability of failure. To ensure the appropriate safety level during the whole structure lifetime. Thus, the RBDO is carried out on the basis of the time-variant reliability analysis. As the structural failure is rarely devoted to only one component, the system reliability approach becomes necessary to deal with realistic application. Finally, the time variant reliability analysis can be used to optimize the predictive maintenance planning.

This thesis aims to develop an efficient methodology for reliable design and predictive maintenance optimization of the jacket taking into account the failure system and by considering the stochastic nature of the loading and uncertainty in the material properties. This approach aims to integrate the temporal aspects, namely the degradation in mechanical performances (fatigue and corrosion) and the probability of occurrence of extreme events. This is an unexplored area of the offshore wind turbine studies, but it involves scientific and economic issues.

References :

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Remarques Didier :

1) A la lecture, les objectifs sont :
   - Time dependant reliability,
   - corrosion & fatigue assesment,
   - extreme event,
   - system reliability,
   - rbdo,
   - maintenance

   Je trouve que ca fait beaucoup d'objectifs simultanées

2) Au niveau de la méthodologie, tu parles d'approche probabiliste et d'intervale (logique floue ?). Il faudrait peut-être définir plus précisément la stratégie à évaluer.

3) Un sujet qui était présent dans la proposition que je t'avais envoyée, c'était aussi de faire des « meta modèles » pour représenter les différentes jonctions soudées.

En conclusion, je ferais peut être une présentation plus précise afin de montrer que l'on sait précisément ce que l'on veut faire dans le cadre de cette thèse, quitte à en faire plus si ca avance bien, mais ca doit rassurer un étudiant. Les points qui me semblent importants : reliability / system / time dependant.