O&M and design challenges of floating wind farm power cables

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126  REE N°5/2019 JICABLE’19 O&M and design challenges of floating wind farm power cables Jean Charvet Emmanuelle Laure Fanny Sbraggia François Gabarrot RTE (France) Context Today: connecting pilot floating wind In 2015 the French State initiated a call for projects for four floating wind farm pilot projects: one in Atlantic Ocean and three in Mediterranean Sea. In 2016, the project developers were awarded. RTE’s mission is to connect these wind farms to the onshore electricity network, in order to transport the energy produced to the consumption areas. These pilot wind farm connections are a key step for RTE to validate the technical solutions that will be deployed on future commercial wind farms for which call for tenders are expected from 2021. Located between 15 and 30 km from the coast, these four pilot wind farms of approximately 25 MW each, will be connected to the existing network by submarine and underground power cable over a total distance of 20 to 35 km and under a nominal voltage of 33 to 66 kV. Commissioning is expected in 2021. Tomorrow: towards mutualization of connection of commercial floating wind Since the law of 30 December 2017, the French State has entrusted RTE with the financing and realization of the connection of the next commercial wind farms, including the offshore transformer substation. Figure 1: Map of main RTE offshore projects including connection of four floating wind pilot projects REE N°5/2019 127 O&M and design challenges of floating wind farm power cables This major regulatory change, inspired by the best standards in force in the North Sea, will enable RTE to fully participate in the success of French ambitions in the
development of marine renewable energies. This reform, by clarifying the role of RTE, will simplify the development of future projects and help reducing the time and cost of developing offshore wind farms. RTE will also be able to build hubs at sea, making it possible to pool the connection of several parks located in the same area. A particularly interesting solution for floating wind farms, entitled to move further away from the coast. The dynamic cable Cable connection to floating structures requires the development of dynamic cables capable of withstanding movements of the floating structure, swell and sea currents. Design and O&M challenges for these specific type of cable connections are described and presented in the following sections. Reliability by design For static submarine cables, prevention of cable damages goes mainly through an appropriate cable routing and protection, while for dynamic submarine cables, it goes mainly through appropriate design of cable configuration from floating platform to seabed. In order to accommodate floating platform displacements under extreme weather conditions, dynamic ancillary equipment such as buoyancy modules are used to give a predefined shape to the dynamic cable, such as “lazy wave” as can be seen in Figure 3. Dynamic cable configuration shall be designed to comply with extreme weather events, as well as fatigue due to repeated movements. It shall also accommodate variation of Figure 3: Principle of connection of a floating wind turbine with the use of dynamic cables. Figure 2: Principle of connection for future commercial Floating wind. Figure 4: Evolution of the lazy wave when considering the effect of Marine Growth. Buoyancy during lifetime of the wind farm. These variations are due to the materials ageing (loss of buoyancy of buoyancy modules and cables) as well as environmental effects such as marine growth. These parameters mean that the dynamic configuration in “start of life” conditions (cable and accessories with maximum buoyancy, and no marine growth) is not the same as in “end of life” conditions (cable and accessories with reduced buoyancy, and marine growth). While dynamic cable configurations such as lazy wave are very common and well documented in the Oil & Gas industry, the specificity of the floating wind farm lies in the water depth, which is far less important than in the Oil & Gas. As a consequence, clearance from seabed and clearance from sea surface become constraints to comply with in the design of the dynamic cable configuration. Designing a cable configuration that can accommodate both “start of life” and “end of life” conditions in water depths around 60 meters may prove to be difficult, because complying with clearance to seabed criteria in “end of life” conditions may mean to infringe clearance to safe surface criteria in “start of life” conditions. It is therefore important to have confidence in the hypothesis taken to define “start of life” and “end of life” conditions, such as marine growth. Density and thickness are really site specifics, as they depend on parameters such as temperature, pH, salinity, currents and of course species identified on site. Some standards exist ([1], [2]), but they have been developed based on data from Oil & Gas sites. For now standards fully applicable to new wind farm areas, such as the French pilot wind farm in Atlantic Ocean and Mediterranean Sea, are lacking. To fill in this lack of knowledge, research projects have been launched. RTE has engaged itself in two of them, which are ABIO+ and APPEAL. These projects are both lead by France Energie Marine, the French reference institute for research on offshore renewable energies. • ABIO+ project has begun in March 2019, for a duration of 3 years, with the objective to characterize biofouling, based on in situ data on French Renewable Marine Energy sites. The effect of dynamic and thermal behaviour of the cable shall also be assessed in the course of the project, as well as methods to determine in situ the thickness and density of marine growth. • APPEAL project has begun in early 2018 for a duration of 3 years, with the objectives to characterize the effects of floating wind farms on coastal socio-ecosystems. A buoy shall be installed on the site of Groix, with a mooring line equipped with biofouling collecting means. RTE’s participation to these projects will ensure to have reliable data to base the preventive maintenance policy upon. Suitable test program One specificity of dynamic cable testing lies in the mechanical testing. Oil & Gas standards provide a good basis but do not address specificities of floating wind turbines cables. Recently, one chapter of CIGRE brochure TB623 has dealt with fatigue analysis and recommendations for dynamic cable type-testing, although many parameters remain to be dis- cussed and defined. RTE is currently coordinating the CIGRE working group B1.63 dedicated to dynamic cables, in order to develop common and clear guidelines for mechanical testing of the whole system (equipment and installation) upon project characteristics (external constraints, active wave, safety factor, etc.). The outcome of this working group, a Technical Brochure, is expected for end of 2020. Monitoring and inspection of cable health For static submarine cables, it is common practice to monitor cable temperature by implementing Distributed Temperature Sensing using integrated fiber optic cables. Development of local hotspots can indicate an internal defect or an unfavorable thermal environment, while local “cold spots” can reveal deburial. Distributed Acoustic or Vibration Sensing can also be considered to help locating deburial or cable fault, but for the specific case of dynamic cable, the most critical parameters to monitor appears to be the mechanical strain and the marine growth development. Strain monitoring Strain monitoring is still in development, but shall prove to be very important to dynamic cables. Monitoring strains along the dynamic cable, and principally along the identified fatigue hot spot(s) would make possible to check that the cable move- ments are not exceeding the ones it has been designed for. Technologies that seem to be the most suitable to dynamic cables are using fiber optics as sensor. To be able to monitor the strain, fiber optics shall be integrated in the cable in a so-called “tight-buffered configuration”, meaning that the fiber optic is mechanically fixed with the power cable. This configuration is different from the standard practice of telecommunication fiber optics that are usually integrated in “loose tube configura- tion” to protect fiber from tension and stresses. The “tight-buffered configuration” needs to be developed with the cable supplier, to adapt the manufacturing process. In “loose tube configuration” fibers are designed with an oversize of about 0.2% in order to anticipate any elongation, meaning that the measurement can only give the information that a constraint 128 REE N°5/2019 JICABLE’19 REE N°5/2019 129 O&M and design challenges of floating wind farm power cables has appeared but cannot quantify the level of constraint on the power cable, whereas in “tight-buffered configuration” a quantitative estimation of cable constraints is possible. Two types of strain monitoring technology have been identified: - Fiber-Bragg strain gauges - Distributed Strain Sensing (DSS) For Fiber-Bragg strain gauges the fiber optic is modified (striated) at identified points (Bragg gauges). A signal sent at a specific frequency in the fiber optic will be reflected by...
the micro grid created by the Bragg gauge in function of the spacing between striae (fringe). When a constraint is applied on the cable, the spacing between the striae is modified and detected by the interrogator at the beginning of the cable. This technology allows for precise measurement with high sensitivity, but only at predefined points of measurement identified at a preliminary stage. Instead of discrete measurement of the constraint (Bragg), at this stage, it would seem more appropriate to get a distributed measurement along the whole dynamic cable, using DSS technology. A laser pulse is sent in a fiber, the signal is reflected by a scattering effect that occurs along the fiber and the back scattering light contains the information of temperature and strain from where it was generated. Figure 5 shows characteristics peaks of the back scattering light: Rayleigh peak that is not sensible to ambient conditions, Raman peaks that only contains temperature information and could be used to measure temperature across the cable length and Brillouin peaks that contain temperature and strain information \((T, \varepsilon)\). The performance of DSS measurement is based on four parameters: • Distance to the interrogator • Sensibility of the measurement • Spatial resolution; the resolution could be improved if the fiber optic core and return inside the cable (loop of fiber optic cable) • Frequency of acquisition In order to monitor every component of cable stress (bending, tension, etc.), it is recommended to integrate three tight-buffered-type fiber optic cables situated at 120° in the cable cross-section and one loose-tube-type fiber optic cable (for example with the telecom fiber) in order to perform the temperature monitoring and to decorrelate the two measurements. The technical challenges that have to be solved are the following: • Resolution, which is linked to frequency of acquisition and distance to the interrogator • Fiber optic integration in the cable design. In tight-buffered configuration, the integrity of the fiber optic shall be tested by the cable supplier, especially on fatigue aspects. Marine growth As explained above, marine growth is an important parameter in the cable configuration design. It impacts the “end of life” conditions (with mass increase and modification of hydrodynamic behavior). Assumptions taken on this phenomena have a direct impact on the cable configuration. Over-conservative assumptions may lead to costly configurations, and even to some impossibility to cope with marine growth, whereas too light assumptions may lead to damaging the cable due to impact on the seabed. That’s why it is important to determine the density, the thickness and the growth velocity of biofouling, by conducting regular measurements. One common assumption in the existing standards is that the biofouling comes to its maximum growth after two years. So a first measurement shall be made at least during the first Figure 5: Scattering effects within fiber optic cables [3], year, and then following measurements shall be made according to the results of the previous ones. Results from ABIOP+ and APPEAL projects shall also be a good basis to define the adequate measurement frequency. In case marine growth exceeds the design assumptions, cleaning will have to be considered. Some tools are already existing to clean biofouling, since this problematic is common to all submerged objects. The tool used will have to be proven safe with regards to the dynamic cable sheath, and with regards to the dynamic ancillary equipment. The tool will also have to be suitable to the type of marine growth species encountered (soft marine growth versus hard marine growth). Controlled and uncontrolled disconnection Heavy maintenance of floating wind turbines requires that the turbine with its floating platform shall be moved to harbor, and thus the dynamic cable to be disconnected from the floating platform. The connection equipment shall be chosen in order to allow for this controlled disconnection and reconnection with minimal loss of cable length (and thus no change of dynamic cable configuration once the reconnection is made). Another event to take into account is the loss of one mooring ring line of the floating platform. Depending on the mooring design of the platform, such an event could lead to large drift of the floating platform, that can’t be accommodated by the dynamic cable configuration. Thus, some weak-link equipment should be installed in order to allow for disconnection of the dynamic cable when the tension load in the cable exceeds a threshold value. This disconnection would probably require the cable to be cut, meaning that it probably won’t be reusable afterwards. Determination of the triggering tension load shall be adressed through a specific study, to ensure that no accidental disconnection will occur during the lifetime of the asset. A study shall also be undertaken to assess the pros and cons of change of mooring design configuration or I-tube fixing devices when compared to the costs of the weak-link equipment and the replacement of the dynamic cable when the weak-link is activated. Spare-parts In order to allow efficient repairs, it is necessary to keep spare-parts of the long lead-time materials of the cable system. Quantity of spares must be carefully addressed depending on risks and failure scenarios to cover. In case of internal or external damage on a submarine dynamic cable, it is anticipated that the whole length of the dynamic cable between the floating platform and the static-dynamic transition shall be replaced, to avoid any joint in the dynamic section of the cable as recommended by applicable standards. Some extra length should also be accounted for in order to make the new static-dynamic transition joint. This extra length needed to perform the joint could be either: • One extra length of dynamic cable (Fig.6) • One extra length of static cable, but requiring one more joint (Fig.7) • Extra length of dynamic cable. Figure 7: Repair scenario - with extra length of static cable. REE N°5/2019 131 O&M and design challenges of floating wind farm power cable. Even if static cable is less expensive than dynamic cable, the most suitable solution will probably be to store extra length of dynamic cable, since it minimizes the number of joints during repair (and doing so, minimizing the time of repair). Dynamic ancillary equipment are also quite long to remain facture, and some quantity shall also be stored. For buoyancy modules, quantity shall take into account: • the probability to lose one or several buoyancy module during the lifetime of the wind farm, • the fact that when replacing the whole length of the dynamic cable, modules shall be transferred from damaged cable to the new one. The clamp of the buoyancy modules may be damaged during this operation, and so it may be advisable to store some of them. Bend stiffener may also be damaged in case of activation of the weak-link, and this probability shall be taken into account when considering the need to store some spare of this accessory. References [1] DNV-RP-C205, 2014, Environmental conditions and environmental loads. [2] DNVGL-ST-0437, 2016, Loads and site conditions for wind turbines. [3] T. Walk, J. Fringe, 2010, Fiber Optic sensing can help reduce third-party threats. Abstract RTE is currently in charge of the connection of floating wind pilot projects to the onshore existing transmission network, which requires the implementation of dynamic cables capable of withstanding...
movements of the floating structure, swell and sea currents. Design, O&M challenges and future developments for these type of connections are presented in this article. Keywords Floating wind farm, Dynamic cable, Marine growth, Strain monitoring, DSS, spare-parts.

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