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Prospects of offshore wind power generation in India

To mitigate the global climate change and to enhance India's renewable power generation capacity and to deploy low carbon energy production with improved energy efficiency, offshore wind generation is being suggested in this paper. Policy and regulatory framework aspects for achieving 5 GW offshore wind installations in the states of Gujarat and Tamil Nadu by the year 2032 with current practices and sophisticated technologies adopted throughout the world is presented. For effective implementation, suitable measures and actions to be taken by various stake holders are also mentioned.

Keywords: *Offshore wind power, policy and regulatory framework, wind power generators, AC-DC power converters, HVDC transmission, offshore substation, power quality/stability studies, wind farms.*

1. Introduction

Throughout the world, the installed wind power generation, which is currently larger than 486.8 GW in the year 2016, and it is expected to exceed 800 GW by the year 2021, making wind energy, as a significant component of the modern and future energy supply systems. 14.38 GW of offshore wind power generation was installed around the world at the end of 2016 as shown in Fig.1. Nearly 12.6 GW of all offshore wind installations are located in European countries, where United Kingdom accounts almost 36% of installed capacity. Unlikely, offshore wind power generation has advantages like higher power generation due to lesser turbulent and roughness, higher plant load factor, reduced bottlenecks in land acquisition/logistics management despite challenges like foundation design in sea, vessel management, O&M aspects than onshore wind energy system. Wind industry created almost 1,155,000 jobs at the end of 2016. In 2016, wind power avoided over 637 million tonnes of CO_2 emissions globally. Totally, 341,320 number of wind turbines spinning around the world at the end of 2016.[1]

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2. Status of offshore wind power generation in India

India, with a vast coastline of over 7,600 km is beginning to explore offshore wind energy as a strategic energy source' to enable long term energy security. In September 2015, India has released its national offshore wind energy policy and the Ministry of New and Renewable Energy was authorized as a Nodal Ministry to promote offshore wind sector. India has initiated the preliminary works of offshore wind development under the European union funded projects, facilitating offshore wind in India (FOWIND) and first offshore wind project in India (FOWPI). Preliminary assessment has started by the National Institute of Wind Energy (NIWE) in the way of installing met masts which acts as representative of offshore wind potential assessment. FOWIND consortium has done studies resource assessment and preliminary feasibility studies along the Indian coast and demarcated eight zones each in gulf of Khambhat, Gujarat and gulf of Mannar, Tamil Nadu, covering areas of 17706 km^2 and 10558 km^2 respectively. Based on FOWIND report, NIWE has initiated the verification and validation of the studies in Gujarat and Tamil Nadu whose demographic areas are shown in Figs.2 and 3. In November 2017, FOWIND consortium successfully commissioned India's first offshore LiDAR, off the coast of Gujarat, in the gulf of Khambhat. [2, 3]

2.1 Various stages involved in offshore wind power generation

Offshore wind power generation has to address the following aspects [4]:

1. Wind resource assessment (WRA), zone selection deals with various tools and techniques used for offshore WRA such as LiDAR/SONAR technology to estimate its potential.
2. Foundations and structures discuss about various types of foundations like monopile, gravity based, jacket type, tripods, high rise pile cap (HRPC) or for latest floating type designs etc.
3. Turbine/generator selection, energy yield discusses about

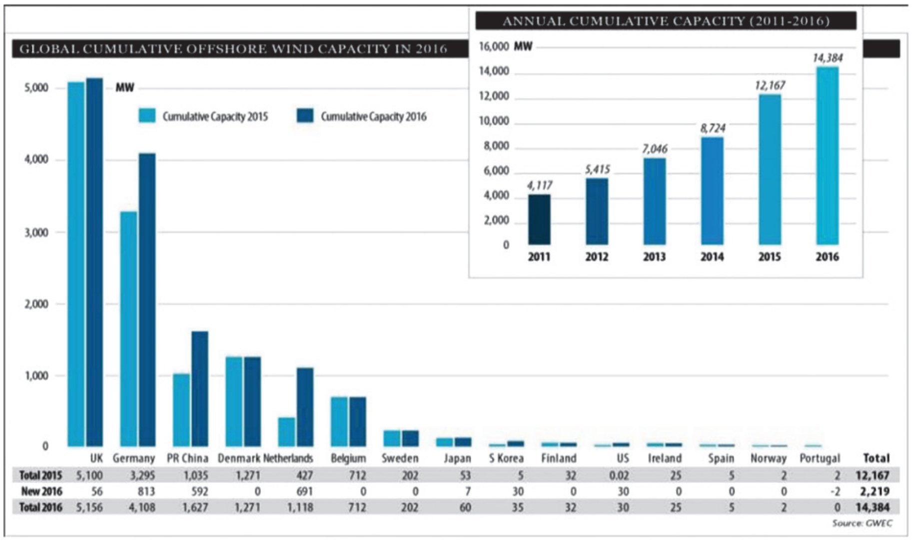

Fig.1 Global and annual cumulative offshore wind capacity of the world in the year 2016

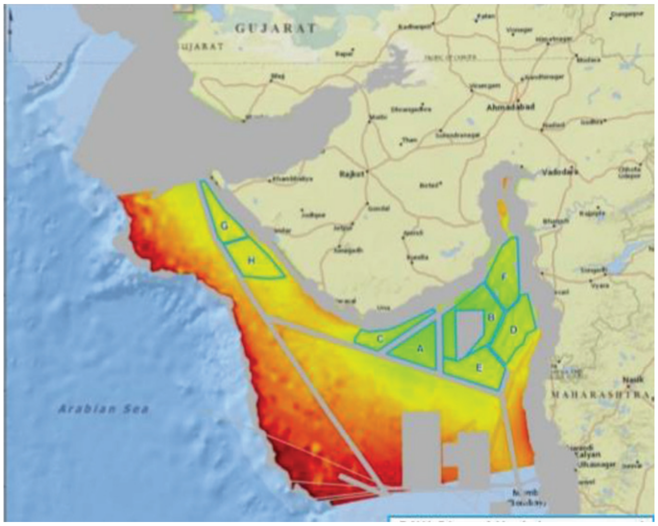

Fig.2 Gulf of Khambhat in the Gujarat region

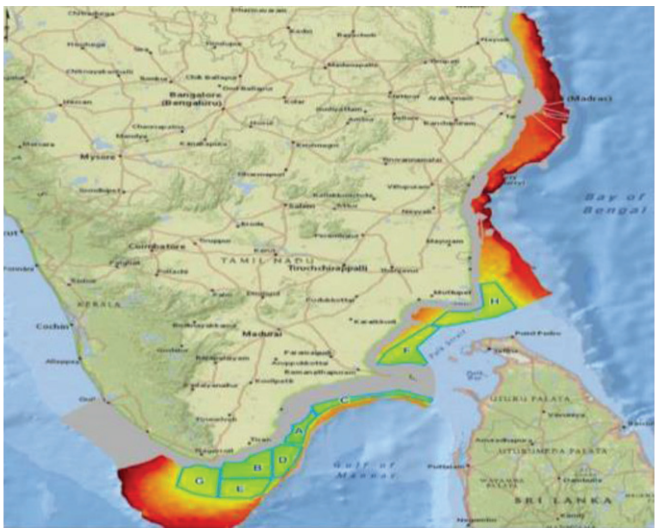

Fig.3 Gulf of Mannar, Tamil nadu

types of wind turbines and power generation

4. Sub-stations deals with both manned offshore and onshore type of sub-stations used for evacuating power from the offshore wind farm to the grid on the mainland.

5. Sub-marine cabling elaborates various power evacuation approaches, submarine cabling and their associated engineering either in form of AC or DC depending upon the economy and size of the project.

6. SCADA and communication describes international standards related to network and communication for offshore wind power projects and their compliance.

7. Marine and ports deals with the requirements and infrastructure at the ports that will be required for developing an offshore wind farm and their respective O&M.

8. Vessels and associated equipment – vessels are the specially designed and most important part of the equipment required in setting up offshore wind turbines, in laying foundations and erecting heavy offshore structures.

9. Other factors like energy yield, operations and maintenance, cost of energy, risks, social and environmental eco-systems.

10. Identification of potential zones for future expansion.

Few successful offshore wind farms implemented around the world are: London Array (630MW) and Greater Gabbard offshore wind farm (504MW), both in United Kingdom, Gode wind farm (582MW) and BARD offshore 1 wind farm (400MW) both in Germany and anholt offshore wind farm (400MW) in Denmark. FOWIND released a report titled, from zero to five GW – offshore wind outlook for Gujarat and Tamil Nadu (2018-2032) during December 2017 [5] lists the policy and regulatory framework aspects of achieving 5 GW offshore wind installations in the states of Gujarat and Tamil Nadu by the year 2032. It addresses five key challenges/enablers for offshore wind and action items for Gujarat and Tamil Nadu as listed in Table. 1

3. Wind energy systems and power electronics

The emerging sizes of wind turbines between 1980 and 2020 are illustrated in Fig.4, where the development of power electronics with its rating coverage and functional role are also indicated. In 2015, the average rating of wind turbines installed in Europe was 2.7 MW for onshore and 4.2 MW for offshore, and now cutting-edge 8-MW wind turbines with a diameter of 164 m are on the market [6]. Fig.4 developments of power electronics for the wind turbines between 1980 and 2020 (E); gray area inside the turbine circle indicates the power rating coverage by power electronics; D means diameter of the rotor.

TABLE 1: FIVE KEY CHALLENGES/ENABLERS FOR OFFSHORE WIND AND ACTION ITEMS FOR GUJARAT AND TAMILNADU

	Key challenges	Key enablers	Action items
1	Complex development process	De-risk development	Clear roadmap
2	Levelised cost of energy	Maritime spatial planning	Consenting and permitting clarity
3	Financing	Demonstration projects	Grid development
4	Infrastructure development: Supply chain, ports and grid	Financial support	Financial support mechanisms
5	Socio-environmental constraints	Long term vision	Competence and skill development

4. Offshore wind power generation technologies

The megawatt range turbines used for offshore wind power generation are the doubly-fed induction machine (DFIM) in which the stator terminals are directly connected to the network while a back-to-back frequency converter provides the controllable voltage to be fed to the rotor terminals, and a full-size converter machine (FSCM) in which a synchronous or squirrel-cage induction machine is connected to the gird via a converter designed for the full turbine rating are given in Figs.5 and 6 respectively.[7]

For the transmission of power from the offshore plant to the grid connection point, choice is to be made between high-voltage alternating current (HVAC) and high-voltage direct current (HVDC) based on line commutated converter (HVDC LCC), or voltage source-based HVDC (HVDC VSC) or modular multi level converter (MMC) as part of the overall project

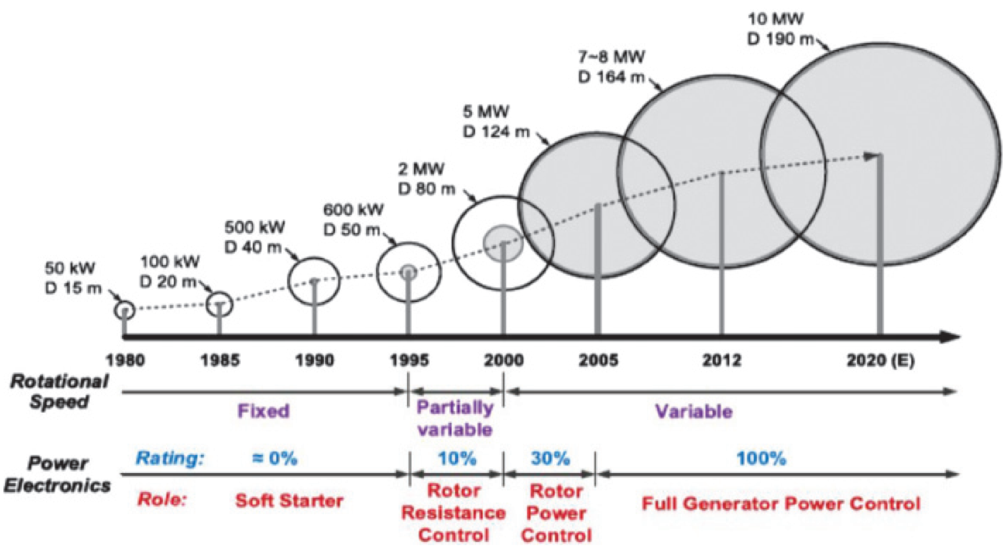

Fig.4 Developments of power electronics for the wind turbines between 1980 and 2020 (E); gray area inside the turbine circle indicates the power rating coverage by power electronics; D means diameter of the rotor.

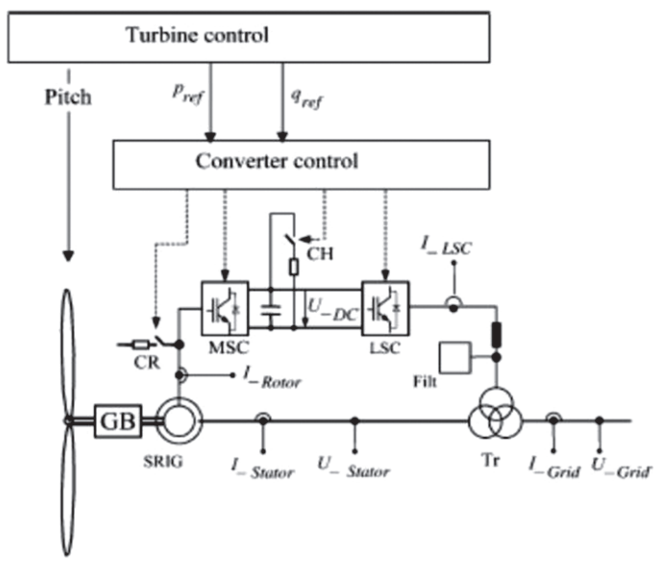

Fig.5 DFIM-based wind turbine

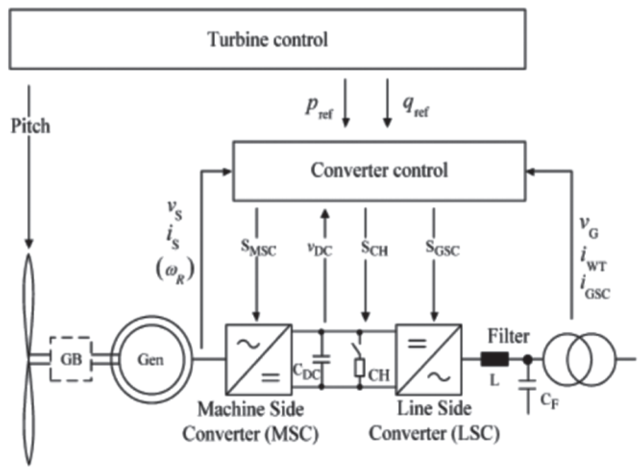

Fig.6 Full size converter-based wind turbine

planning process [8]. A typical technological solution for offshore wind farms connection is shown in Figs.7 and Fig.8.

5. Smart grid technologies and communication infrastructure for offshore wind farms

Addressing electrical design issues in offshore power networks, smart grid technologies having the features of increased reliability, flexibility and efficiency to mitigate the particular issues of transmission and distribution of power in offshore wind farms [9] are listed as:

1. High temperature super-conducting cables,
2. FACTS (flexible AC transmission systems) devices such as SVC, STATCOM, fault current limiters, voltage control and VAR support devices and unified power flow controller (UPFC).

Wind power plant communications network provides a communications link between the wind turbines and the wind plant control system. This includes the physical components (wires, transducers, fiber optics, repeaters, and switches) and software protocols like (ethernet, TCP/IP, wireless, zigbee, passive optical network) that are used to transmit

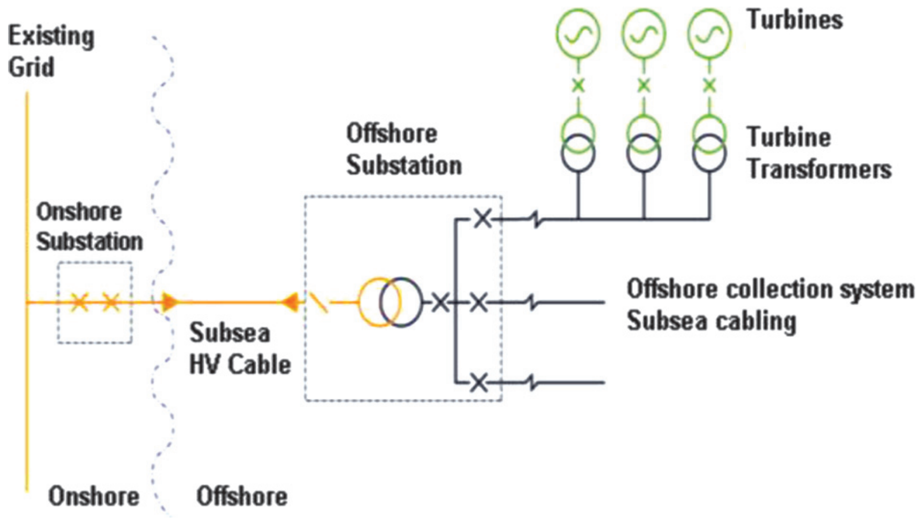

Fig.7 Offshore wind farm transmission

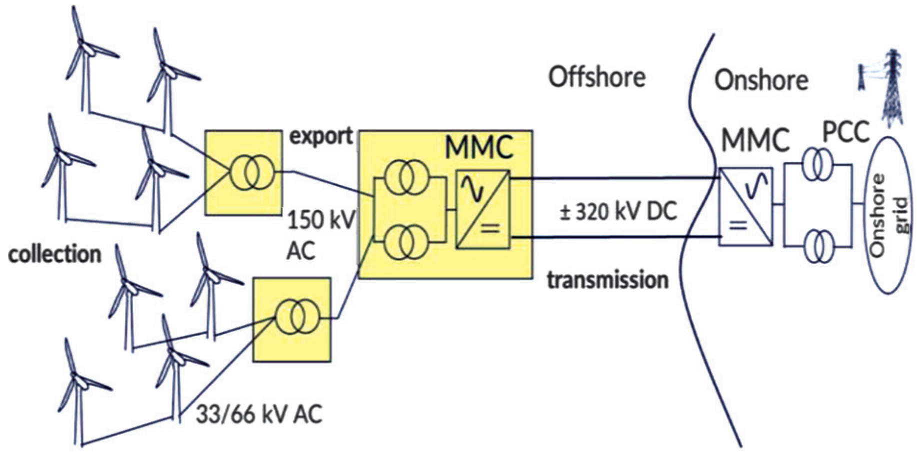

Fig.8 Long distance offshore wind farms connection

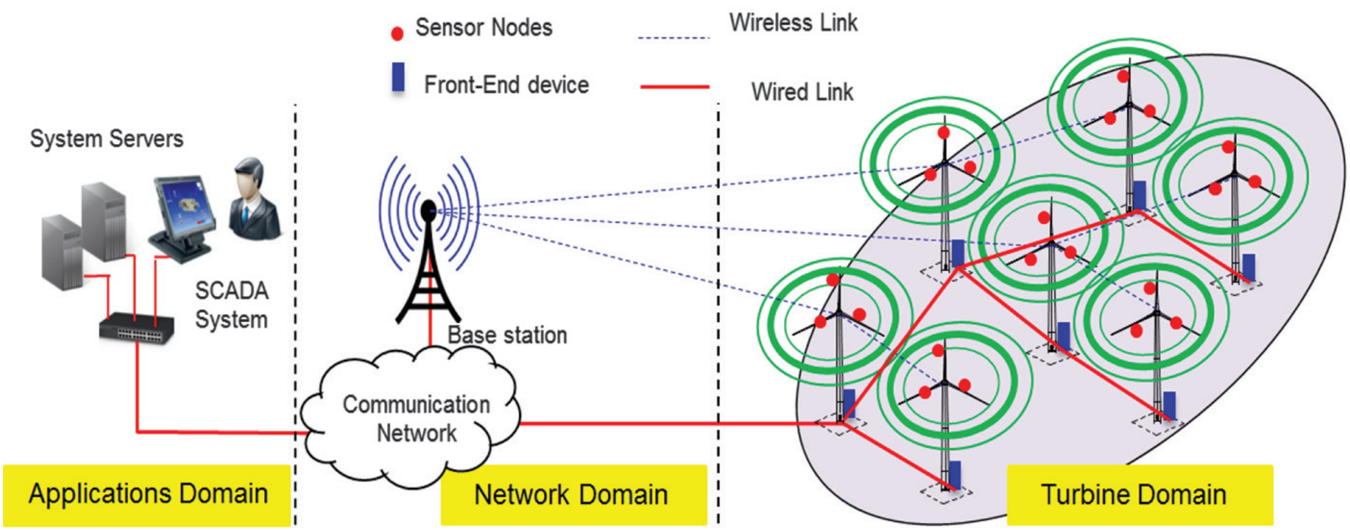

Fig.9 Communication ntwork architecture for offshore wind farms

information between the wind turbines and the wind plant control system. The standard IEC 61400-25 covers components required for the operation of wind power plants [10, 11]. The offshore wind farm communication network of its SCADA system owns individual connection between the wind turbines and the control center, and relatively independent from the public power grid. Although the transmission distance of an offshore wind farm is quite long compared to a LAN for a substation network, the communication network within an offshore wind farm can still be treated as a local area network (LAN), which is illustrated in Fig.9. Here, the controllers on each wind turbines collect all necessary data from the devices of the wind turbine, and transfer the data to the control center of the wind farm; also they assign the commands from the control center to the devices to control the wind turbines. The communications between the controllers and the control center computer are conducted via a SCADA communications network.

6. Power system technology impact assesment studies in offshore wind farms

Following research studies have to be carried out to study the effects like stability and power quality issues when connecting offshore wind power generation to a power system [12] as mentioned below:

1. Risk evaluation of submarine HVAC/HVDC cable system design and protection studies for array and export cables.
2. Development of electrical grid design including FACTS devices and design guidelines for smart grid communication infrastructure with the existing power system.
3. Erection of offshore substation, HVAC/HVDC system and support structures for wind farms addressing lightning and emergency response protection due to onshore disasters/geo-hazards.
4. Impact study on power system stability and power quality improvement for wind power system.

Further, onshore wind power project implementation needs grid planning and development, low cost financing like viability gap funding and national clean energy fund support, sectoral capitals, carbon trading mechanisms, environmental/ met station/geophysical/geotechnical surveys, power evacuation studies and inter agency coordination by government/policy makers/statutory/certification bodies; competence, wind turbine/generator development, condition monitoring system, R&D investment, global collaborations and project financing by prospective project developers and suppliers/manufactures, financial institutions and investors, marine developers/vessel operators, cable manufacturers, through near shore/deep water/floating projects. Also it should address future issues like reduction in levelized cost of energy, increased investor confidence, environmental/ human impact assessment and public acceptance.

7. Conclusion

Offshore wind power generation has experienced a major transformation in terms of both the level of installed capacity and the technological maturity. It seems there is significant growth potential in this technology in future. In this paper, the current status and future prospects of offshore wind power generation in India is detailed. Progress made in wind energy systems associated with power transmission technologies is also detailed. Future developments including smart grid and communication infrastructure needed are also dealt. Few successful case studies adopted in different parts of the world have been surveyed. A list of works to address technology impact assessment for offshore wind power generation is also mentioned.

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