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RESEARCH ARTICLE

POWER TRANSMISSION OF LOW FREQUENCY WIND FIRMS

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Abstract: The future for wind power generation in Germany is offshore wind energy. The preferred concept for power transmission over long distances from the offshore wind farm to the mainland is the High Voltage Direct Current (HVDC) power transmission. In this paper a new transmission concept based on HVDC is presented.
Keywords: HVDC, power transmission, thyristor, IGBT, VSC, offshore, wind farm, wind power, transmission line, wind park, distribution of electrical energy, power quality, Voltage Source Converter (VSC)

I. INTRODUCTION

Offshore wind power plants are expected to represent a significant component of the future electric generation portfolio due to greater space availability and better wind energy potential in offshore locations [1], [2]. The integration of offshore wind power plants with the main power grid is a subject of ongoing research [3]–[5]. Presently, high-voltage ac (HVAC) and high-voltage dc (HVDC) are well-established technologies for transmission [6]. HVAC transmission is advantageous because it is relatively straightforward to design the protection system and to change voltage levels using transformers. However, the high capacitance of submarine ac power cables leads to considerable charging current, which, in turn, reduces the active power transmission capacity and limits the transmission distance. HVAC is adopted for relatively short (up to 50–75 km) underwater transmission distances [7]. Two classes of HVDC systems exist, depending on the types of power-electronic devices used: 1) line-commutated converter HVDC (LCC-HVDC) using thyristors and 2) voltage-source converter HVDC (VSC-

HVDC) using self-commutated devices, for example, insulated-gate bipolar transistors (IGBTs) [8]. The main advantage of HVDC technology is that it imposes essentially no limit on transmission distance due to the absence of reactive current in the transmission line [9]. LCC-HVDC systems are capable of handling power up to 1 GW with high reliability [7]. LCCs consume reactive power

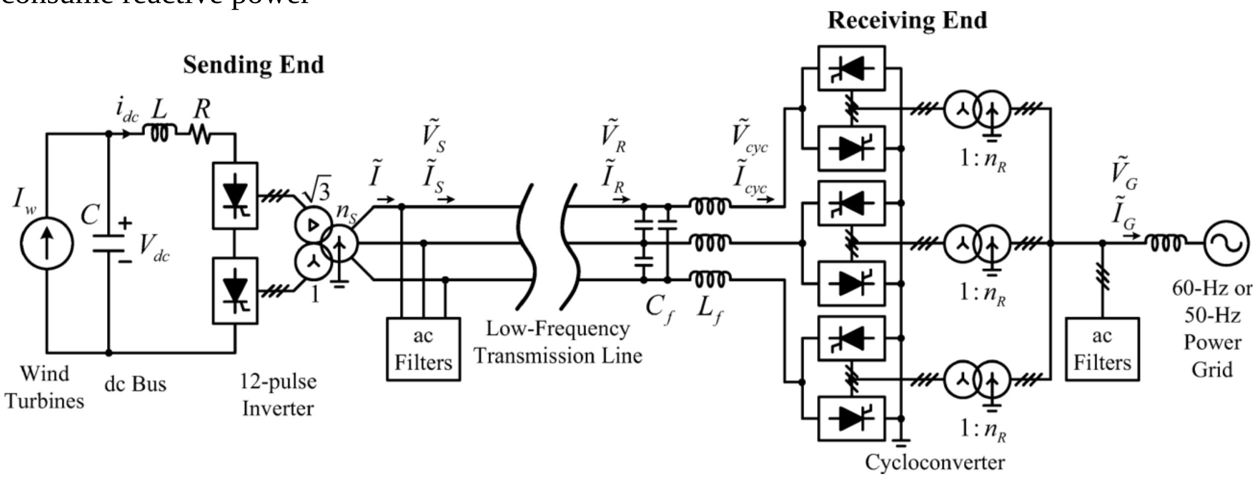

Fig 1.0 Configuration

II. THYRISTOR-HVDC

The classic HVDC, that is used for some decades now, is based on thyristors as power electronics devices (Fig. 1). The thyristor-HVDC is a proven technology and available for transmission power up to some gigawatts. But the thyristor-HVDC has some disadvantages. The thyristor-rectifier and the thyristor-inverter need reactive power and filtering for an operation with good power quality. The grid-voltages and - currents can be seen later in Fig. 3. It is also a problem to create a voltage-system offshore to supply the offshore wind park with energy during the installation, times of no wind and starting-up operation. The thyristor inverter needs reactive power for the commutation that has to be supplied by a strong supply grid or a reactive power source like a big synchronous generator that is connected to the offshore grid.

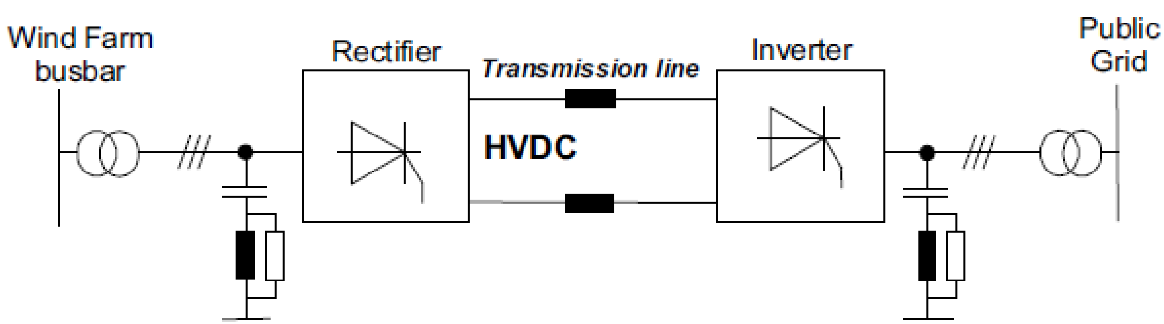

Fig 2.0 6-pulse and 12-pulse thyristor

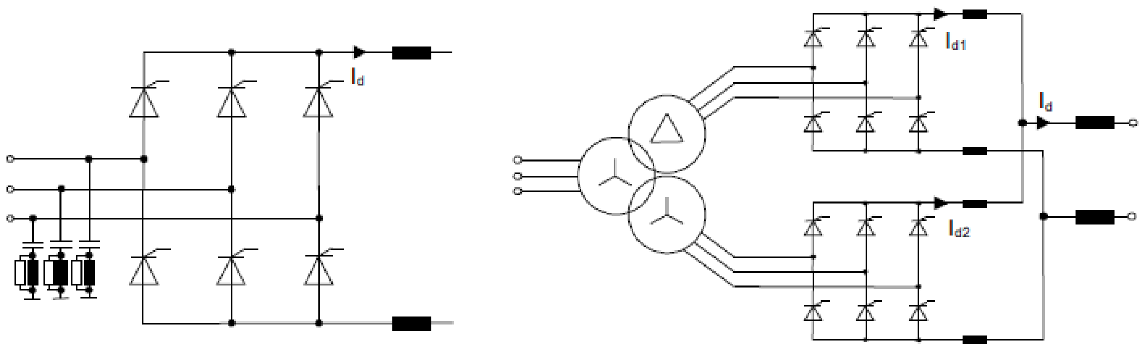

Fig 3.0 Thyristor unit

The thyristor-HVDC-Transmission is more expensive than a conventional a. c. solution for short distances. Nevertheless, HVDC may well be used for many offshore wind projects, because [2]:
− HVDC provides a power transmission with very high capacity over only two d.c. cables.
− HVDC has no restrictions for the transmission distance in principle.
In Fig. 3 the simulated voltage and the current of a thyristor converter are shown. The phase shift between the voltage and the current and also the harmonic content of the current can be seen.

III. IGBT-HVDC

The fast changes in the field of power electronic devices with turn off capability like IGBT benefit the development of Voltage Source Converters (VSC) for HVDC applications. Fig. 4 shows a VSC-HVDC transmission, where the offshore IGBT-Unit rectifies the a. c. wind park voltages to get a d.c. voltage. The inverter onshore creates a three phase a. c. voltage to feed the energy into the public grid. In Fig. 5 you can see a IGBT-Units in detail.

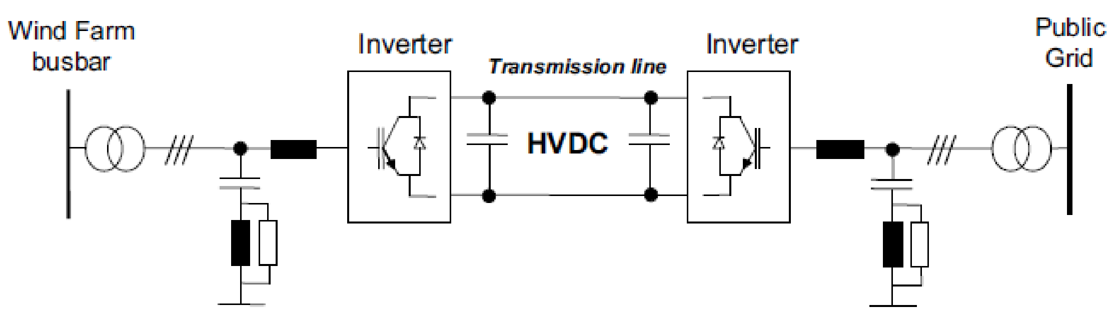

Fig. 4. Structure in Principle of IGBT-HVDC

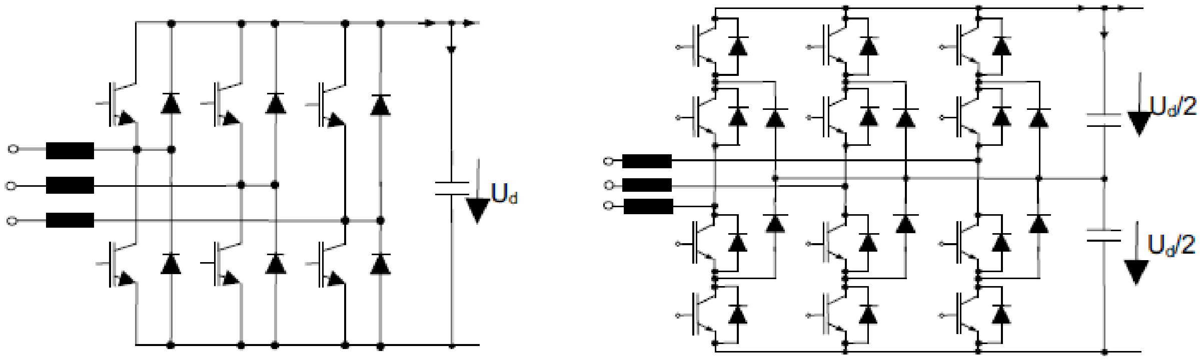

Fig. 5. IGBT-Unit, (2-Level left, 3-Level right)

IV. SIMULATION MODEL

The simulation model of the parallel operation of the thyristor- and the IGBT-HVDC can be seen in Fig.10. The different units operate with the following control strategy. Power transmission from the offshore wind park to the mainland is done by the Thyristor-HVDC and the IGBT-units are working as SVC (static var compensation).

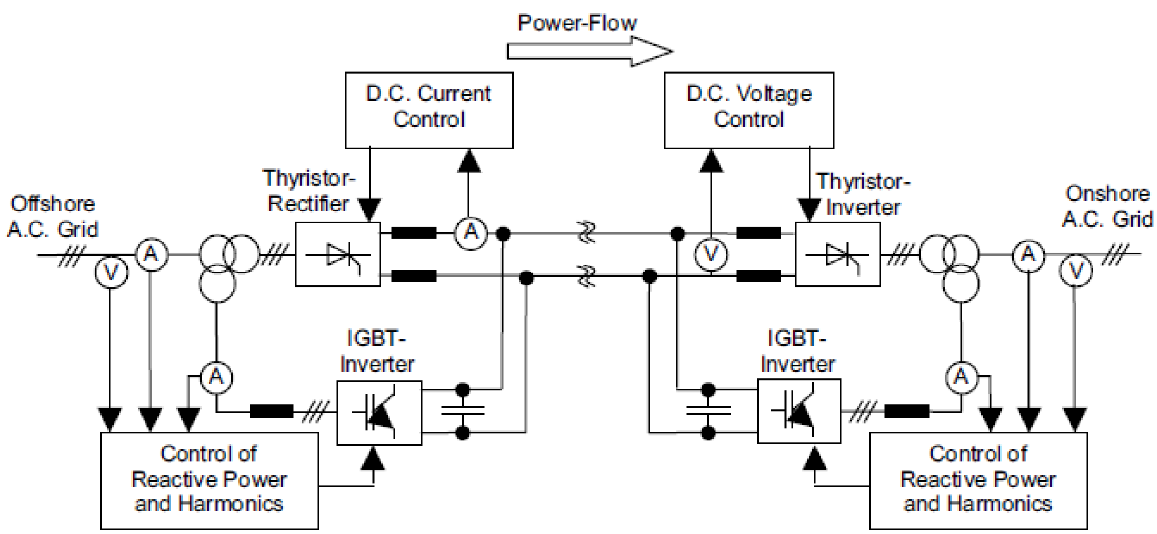

Fig 6.0 Simulation Model of Parallel operation of thyristor- and IGBT-HVDC

The thyristor-offshore-unit controls the d.c. current and the onshore-unit the d.c voltage. The IGBT-HVDCs are working as SVC (static var compensation) and compensate the reactive power and the harmonics of the thyristor-HVDC. The resulting a.c. offshore current can be seen in Fig. The IGBTs switch fast between fixed voltage levels. The desired a. c. waveforms are reached by a pulse width modulation (PWM) and low pass filtering, which can be seen in the simulation in Fig. 6. So it is possible to create a voltage system offshore to supply the wind park with energy during installation and times of no wind. IGBT- -HVDC provides independent control of reactive power at the converter stations, which could be a great benefit in increasing the power quality in the public grid. HVDC provides almost no contribution to fault currents, which in many areas are a major limitation on the connection of a new power station. In addition to full power flow control in both directions, the IGBT-HVDC system can prevent fault propagation, increase low frequency stability, reduce network losses and increase voltage stability. But on the other hand the power range of the IGBT-HVDC is only about some hundred megawatts, which is not enough for the big wind farms built in the North Sea.

V. CONCLUSION

A low-frequency ac transmission system for offshore wind power has been proposed. A method to design the system's components and control strategies has been discussed. The use of a low frequency can improve the transmission capability of submarine power cables due to lower cable charging current. The proposed LFAC system appears to be a feasible solution for the integration of offshore wind power plants over long distances, and it might be a suitable alternative over HVDC systems in certain cases. Furthermore, it might be easier to establish an interconnected low-frequency ac network to transmit bulk power from multiple plants. In order to make better-informed decisions, it is necessary to perform a complete technical and economic comparison among HVAC, HVDC, and LFAC, evaluating factors, such as the transmission efficiency, investment and operating costs, and the performance under system transients.

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